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APPLIED MECHANICS REVIEWS

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RECENT STUDIES ON FLAME STABILIZATION OF PREMIXED TURBULENT GASES[1]

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I. INTRODUCTION

FLAME stabilization is of importance in the practical design of ramjets and afterburners. It has been studied extensively in recent years, particularly with reference to bluff-body flame-holders. In the present survey we describe the investigations relating to flame holding by bluff bodies as well as new techniques (e.g., flame holding by the use of reverse jets) which may prove to be of practical importance in new engine configurations.

In Section II we consider the flow field downstream of a bluff-body flame-holder which includes the recirculation zone behind the body and a region of flame spreading farther downstream. Explicit reference is made to crucial experiments which illustrate the nature and magnitude of the velocity field, the physical extent, the temperature, and the gas composition of the recirculation zone. Experimental studies and theoretical predictions of the angle of flame spreading, as well as some observations on unstable flow and the onset of blowoff, will be reviewed.

The variation of blowoff velocity with flame-holder design, pressure, and mixture composition is considered briefly in Section III both for single and for adjacent bluff bodies. Also included is a summary of results for blowoff velocities obtained with a reverse-jet flame-holder and with wall recesses.

Theoretical studies on the mechanism of flame stabilization form the subject of Section IV. We shall indicate the points on which various proposed models agree and disagree with experiment and attempt to formulate a composite description which is consistent with most of the currently available experimental data both for bluff-body and for reverse-jet flame-holders.

II. FUNDAMENTAL STUDIES RELATING TO THE RECIRCULATION ZONE BEHIND BLUFF BODIES AND WAKE SPREADING

A. Schematic Representation of a Fully Developed Turbulent Wake Behind a Bluff Body

In Fig. 1 we present a schematic summary of the recirculation zone and downstream flame-spreading region which is consistent with the experimental results which will now be described in greater detail.

B. The Recirculation Zone

The existence of a region immediately behind the flame-holder (see Fig. 1), in which almost completely burned fluid performs a vortex-type motion (which includes recirculation and reverse flow near the axis), has been demonstrated by a number of experiments. The recirculation zone differs in its essential features from the alternate vortex shedding for cold flow which is a well-known phenomenon and is referred to as the Kármán vortex street.

A number of ingenious methods have been devised to observe the flow in the recirculation zone.

Nicholson and Field (1)[2] have used several different techniques for observation of propane-air mixtures passing a two-dimensional bluff-body flame-holder both with and without combustion. Some of the methods applied are the following: (a) Aluminum powder was mixed with the gas so that the

[1]Supported by the Office of Ordnance Research, U. S. Army, under contract DA-04-495-Ord-446.

[2]Numbers in parentheses refer to the references at the end of the paper.

streamlines became visible and could be photographed. This procedure revealed the effect of the flame on the flow field. An increase in flow blockage and the absence of vortex shedding were demonstrated. (b) High-speed schlieren and shadow motion pictures of steady and unsteady combustion were taken with ordinary light sources as well as with sparks lasting only a few microseconds. The schlieren motion pictures were more effective than the shadowgraphs and indicated the sequence of ignition and blowoff (see Section II D for details). (c) By introducing sodium acetate or carbonate into the wake region, the flow pattern within the wake could be identified through emission of the yellow light characteristic for the sodium D lines. The emitted intensity was sufficient to allow photography at 5000 frames per second. These tracer studies showed the

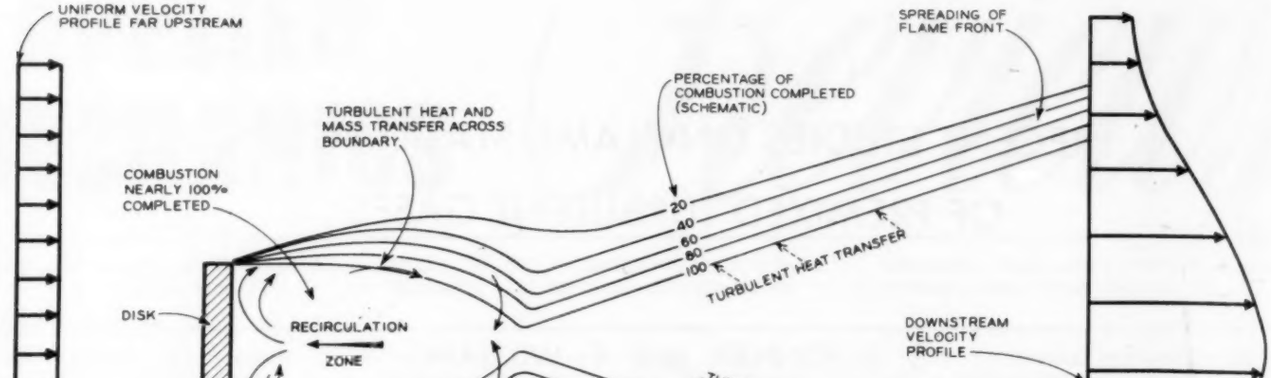

FIG. 1. RECIRCULATION ZONE AND FLAME-SPREADING REGION FOR A FULLY-DEVELOPED TURBULENT WAKE BEHIND A BLUFF-BODY

recirculation zone immediately behind the flame-holder. Thus fluid particles travelled from perhaps two baffle lengths downstream all the way upstream to the base of the flame-holder. This upstream motion was observed to occur randomly throughout the wake for a flow velocity of 200 ft/sec and a ¼ inch wide flat-plate baffle (Reynolds number $\simeq$ 10,000). The reverse-flow velocity was found to be as high as 65 ft/sec in some cases. The residence time of a small volume element of fluid in the recirculation zone was about 0.008 sec. (d) Direct high-speed photography of the flame front was made possible by augmenting the brightness of the flame through the addition of vaporized sodium salt to the combustible mixture.

Westenberg et al. (2) have recently described another method for tracing the flow pattern in the wake region. Sampling of the gases in the recirculation zone, with helium injection from a conical one-inch flame holder, was used to indicate the flow pattern for very lean pentane-air flames at the exit of a 6-inch pipe with flow velocities from 20 to 53 m/sec. The concentration profile of the helium tracer, which was measured as a function of position, showed absence of violent mixing in the recirculation zone but verified the hypothesis of reverse flow near the middle of the wake region. Mixing occurred near the edge of the baffle; the mixing zone thickened and became more turbulent downstream. No evidence of alternate vortex shedding was observed. The length of the recirculation zone was found to vary with equivalence ratio but to be independent of approach stream velocity. The ratio of recirculation zone length L to flame-holder diameter D was found to be different for disks and cones. Possibly the Reynolds numbers were too low to produce a fully developed turbulent wake.

Illuminating studies of the flame-holding mechanism have been performed by Zukoski and Marble (3, 4, 5). These authors have shown that the temperature of the gases in the recirculation zone, as determined from line-reversal studies using the sodium D lines, remained practically constant and close to the adiabatic flame temperature as flame blowoff was approached. The blowoff conditions were shown experimentally to correspond to the critical value unity for the first Damköhler similarity group, i.e.,

$$D_I = (L/V_{BO})(1/\tau) = 1. \qquad [1]$$

Here L is the wake length and τ represents an effective chemical (combustion) conversion time; the ratio L/V_{BO} equals a minimum convection (residence) time for chemical conversion if V_{BO} is the blowoff velocity. For $V > V_{BO}$ blowoff occurs, whereas for $V < V_{BO}$ a stable recirculation zone and flame holding are observed. The chemical time τ is a characteristic of the fuel-air mixture under study.

Schlieren photographs obtained by Zukoski and Marble (3,4) illustrate the change to fully developed turbulent wakes for the experimental conditions in which L/D was observed to become independent of approach stream Reynolds number. This phenomenon is similar to the well-known transition from laminar to turbulent wakes occurring for cold flow with increasing Reynolds number (6). The length of the recirculation zone was defined experimentally (4) within 5% by salt injection. While the ratio of wake length to flame-holder diameter was

found to be constant for Reynolds numbers exceeding about 10^4 for cylindrical flame-holders, the wake length was found to vary roughly as the square root of the flame-holder dimension for lower Reynolds numbers. This last result is to be ascribed to fluid-dynamical blockage effects of the walls.[3]

Early schlieren photographs were taken by Scurlock (7) who found that the extent of wake turbulence increased with increasing flame-holder dimensions, with increasing free-stream velocity, and with increasing turbulence in the approach stream.

C. The Wake Combustion Profile

Sampling of combustion products and reactants in the wake (2) has indicated that the gas in the recirculation zone is essentially completely burnt, an observation which is in agreement also with flame-temperature measurements made by the sodium D-line reversal technique (3, 4). The contours of the combustion efficiency curves (see Fig. 1) show that burning becomes more complete as the axis of the flame-holder is approached. The physical region in which combustion occurs therefore appears to include the entire space between the outside flame region and the recirculation zone. Furthermore, for the experimental conditions described in reference (2), the rate of increase of combustion efficiency with linear distance appears to be substantially uniform. Increase in the upstream turbulence level did not affect stability to an important extent.

Careful observations of the luminosity from some lean mixtures[4] show that the intense CH and C_2 radiation is confined to the region between the flame front and the recirculation zone. The intense blue-green emission identifies the spacial region in which most of the chemical reactions occur.

The extent of completion of combustion can also be estimated from the measurement of axial pressure distribution in a duct in which combustion is taking place (7, 8, 9).

D. Ignition, Blowoff and Flame Spreading Downstream from a Bluff Body

Flame spreading downstream of the flame-holder has been investigated experimentally by the use of direct and schlieren photography. Steady-state burning, as well as blowoff, ignition, and unstable burning have been studied in this manner.

Ignition with a spark located upstream of or at the flame-holder starts from the wake region immediately behind the flame-holder and then propagates downstream by extending "horns" of flame alternately from the upper and lower edges of the flame-holder (1). These horns curl over, envelop and consume large volumes of combustible mixture; they suggest the existence of alternate vortex shedding before ignition.

Observations of the sequence of events (1, 7) which occur in blowoff indicate that the flame is first extinguished downstream and that the point of extinction then moves to the flame-holder. For approach velocities close to the blowoff velocity, the zone of flame spreading disappears and only a small region of burning remains immediately behind the flame-holder. As the blowoff velocity is finally approached, the flame is completely extinguished. For some experimental arrangements blowoff may be accompanied by unsteady burning and pulsations. In these cases the blowoff sequence is essentially the same as described above except that combustion oscillations occur. This phenomenon has been observed by Nicholson and Fields (1) at the rich blowoff limit.

Both theoretical and experimental investigations of steady-state flame spreading have been carried out (10–14). Williams et al. (14) found that the rate of flame spreading is largest for stoichiometric fuel-air mixtures and decreases for both lean and rich mixtures. Since increasing approach stream turbulence had no effect on the rate of flame spreading, one may infer that the wake was always turbulent in the flame-spreading region. Increasing the flame-holder diameter did not influence the rate of flame spreading until blockage effects became important; also the shape of bluff-body flame-holders had little effect on flame spreading. An increase in the approach stream velocity was found to lead to a decrease in the rate of flame spreading except for very lean mixtures where there was evidence that alternate vortex shedding had begun (14). For these lean mixtures the increase in flame width with increasing velocity was attributed to increased rate of vortex shedding; support for this last interpretation was obtained from the fact that an increase in flame-holder diameter, which increases Reynolds number and, therefore, the rate of vortex shedding, was also found to increase the rate of flame spreading.

The process of flame spreading was first studied by Scurlock (7), who assumed that the flame speeds corresponded to very high turbulence levels which increased greatly with approach stream velocity. Both theory and experiment (14) show that there are regions of high velocity gradient near the flame-holder and also downstream where the velocity of the burnt gas exceeds that of the unburnt gas. Between these two zones is a region of low velocity gradients in which the flame sometimes "necks" down. More refined theoretical treatments of flame spreading, utilizing assumptions similar to Scurlock's, have been developed (10–13).

III. EXPERIMENTALLY DETERMINED BLOWOFF VELOCITIES AND CORRELATION OF DATA

In this Section III we summarize some of the important experimental results obtained for flame stabilization behind bluff bodies (Section IIIA), stabilization by opposed and transverse fluid jets (Section IIIB) and in recessed ducts (Section IIIC), and flame stabilization behind two or more adjacent bluff bodies with engineering applications.

A. Flame Stabilization Behind a Bluff Body

As early as 1943 Wolfhard (15) observed flame stabilization on a cylindrical obstacle and showed that the blowoff velocity was dependent on cylinder diameter and pressure for a given combustible mixture. Since this time, a number of investigators have measured the variation of blowoff velocity with flame-holder dimension and design, mixture composition, pressure, etc. (3, 7–9, 14, 16–28). De Zubay (17), using (commercial) propane-air mixtures and disks with diameters of ¼ in., ½ in., and 1 in., measured the blowoff velocity for pressures varying from 3 to 15 psia and linear flow velocities between 40 and 550 ft/sec. An acceptable correlation (maximum scatter ±30%) for all of the observed blowoff data was obtained by plotting the fuel-air ratio as a function of $V_{BO}/P^{0.95}\,D^{0.85}$, where V_{BO} is the linear flow velocity at blowoff past the disk, P equals the pressure in the plane of the disk, and D represents the disk diameter.[5] This correlation is in good accord with the earlier work of Scurlock (7) and of Longwell (19). For given physical conditions, De Zubay found that the maximum blowoff velocity occurred for slightly rich gas mixtures. Variations in pressure did not appear to effect significant changes in the luminosity and shape of the combustion region. This same author reported subsequently (18) that, with the same physical apparatus but using hydrogen-air mixtures in place of propane-air mixtures, experimental data were obtained which were best correlated by plotting fuel-air ratio as a func-

[3] E. E. Zukoski, personal communication.
[4] E. E. Zukoski, personal communication.
[5] In accord with the correlations described in reference 3, it appears that De Zubay's results refer to an intermediate Reynolds number range before a fully-developed turbulent wake is obtained.

tion of $V_{BO}/P^{0.61}\ D^{0.74}$. Similarly, Longwell et al. (19) found that, if only the fuel-air ratio and the diameter of the flame-holder are varied, then, for hydrocarbon-air flames stabilized by circular cylinders mounted axially, V_{BO}/D depended only upon the fuel-air ratio. Scurlock (7) performed experiments in a constant-area duct with both two- and three-dimensional flame-holders; for the latter his data were correlated by plotting $V_{BO}/A^{0.45}$ as a function of fuel-air ratio where A is the area of the flame-holder normal to the flow direction.

The correlation of Zukoski and Marble (3) for fully developed turbulent flow in terms of the first Damköhler similarity group has been given in Eq. [1]. Since the wake length L was found to be a linear function of bluff-body diameter, these results clearly show a linear dependence of V_{BO} on D for a given combustible mixture. Results which are in accord with this last conclusion have been reported also by other investigators (20–22). To summarize, the available data are consistent with the idea that, for three-dimensional flame-holders, V_{BO} is a linear function of obstacle diameter for constant flow blockage provided the Reynolds number is sufficiently high.

Williams and Shipman (22) have prepared the following summary for the dependence of maximum blowoff velocity on various parameters: (a) Stability is best for systems with low ignition energy and high flame velocity. (b) Stability increases somewhat with mixture temperature. (c) Increase of flame-holder temperature increases stability (14, 23–26). (d) An increase of turbulence intensity either decreases (7) or increases stability so that the effect of entering stream turbulence is not clear. (e) Although stability increases with pressure, the detailed variation of blowoff velocity with fuel-air ratio changes (27). (f) A two-dimensional stabilizer in a rectangular duct seems to be more effective than a three-dimensional stabilizer (disk or sphere) in a duct (28). (g) For sufficiently large stabilizers, stability decreases because of wall blockage effects. (h) Increasing noise may decrease stability. Most of these summary statements are obviously in accord with the picture of the flame-holding mechanism sketched in Fig. 1 and with the correlation given in Eq. [1].

B. Flame Stabilization with Opposed and Transverse Fluid Jets

Turbulent flames have also been stabilized successfully with an opposing fluid jet (29–32). The geometric configuration of the experimental arrangement, including the recirculation zone and critical region for flame holding, is shown schematically in Fig. 2. The flame is stabilized around the stagnation region which is located at a small distance (the distance depends, of course, on the relative flow velocities of the primary and jet streams) upstream from the outlet of the jet tube.

Experimental measurements of rich and lean limit blowoff velocities (29–32) show that the observed blowoff curves depend significantly on the chemical nature of the jet stream (which contributed only about 1% to the total mass flow) under otherwise fixed experimental conditions. Since the heat release rate for hydrocarbon-air mixtures is generally greatest for mixture compositions which are nearly stoichiometric, one might expect the highest blowoff velocities to correspond to a nearly stoichiometric gas mixture in the critical region for flame stabilization (see Fig. 2). In accord with this hypothesis (and with the idea that the combustible gas composition in the critical zone is determined largely by the approach stream and jet mixture compositions), it has been shown for propane-air flames that: (a) For a stoichiometric fuel-air mixture in the opposing jet stream, the maximum blowoff velocity corresponds to an equivalence ratio close to unity (30, 32). (b) For an air jet, the maximum blowoff velocity corresponds to rich fuel-air mixtures. (c) For an oxygen jet, the lean limit blowoff curves are displaced to equivalence ratios less than unity. Quantitative calculations based on the assumption that the mixture composition in the critical region is nearly stoichiometric and that the recirculating gas contributes no combustible material will be discussed in Section IV B.

The opposing jet flame-holder provides relatively wide blowoff limits and high blowoff velocities. Furthermore, because of the pronounced effect exercised by the jet-stream composition, blowoff limit curves can be shifted significantly from one equivalence ratio to another, a fact which may be used to advantage in the operation of propulsion devices at greatly different altitudes.

Transverse fluid jets with a large range of velocities and mixture compositions have been tested for their flame-holding ability; in all cases the flame could not be stabilized (32). Also two and four opposing transverse jets were found to be ineffective. Perhaps transverse jets do not function as flame stabilizers because they are not capable of slowing down the main gas flow to form a well-defined stagnation region.

C. Flame Stabilization in Recessed Ducts (33)

Premixed turbulent propane-air flames have been stabilized in a rectangular duct by using various types of wall recesses (33). With properly designed wall recesses, the blowoff velocity versus equivalence ratio curve showed significantly wider stability limits than a relatively poor V-gutter type bluff-body flame-holder. At the same time, a significant reduction in pressure drop was achieved.

The heat transfer to the duct wall in the vicinity of a recess is greatly increased by the recirculating gases which anchor the flame. In fact, there must be a direct correlation between efficiency of flame stabilization and exaggerated convective heat transfer. The observed blowoff limits for a variety of symmetrically located wall recesses showed substantially equivalent results provided (a) the recess was sufficiently deep to support an adequate amount of recirculating gas, (b) the slope of the recess at the upstream end was great enough to produce flow separation, and (c) the geometric construction of the lip was not conducive to initiating and supporting flow oscillations, as seemed to be the case with a semicircular upstream end for the wall recess. For the symmetrically arranged recess flame-holders, the flame fronts spread across the duct and merged downstream. The rate of flame spreading was relatively smaller than for a V-type gutter, thereby necessitating the use of longer ducts. Schlieren pictures downstream from the recirculation zone revealed the presence of distorted flame fronts which may have been produced by transverse oscillations.

Without the development of special techniques for efficient wall cooling, such as film cooling around recesses, the use of wall-recirculation zones for flame holding does not appear to be a practically useful technique.

D. Flame Stabilization Behind Two or More Adjacent Bluff Bodies; Engineering Applications

The stability characteristics of flames stabilized by means of a group of bluff bodies placed sufficiently far apart are, as one would expect, substantially the same as those of a flame stabilized by means of a single bluff body. In particular, the curve of blowoff velocity versus fuel-air ratio is the same (14). If, however, the bluff bodies are in close proximity, then flow blockage and interaction occur which produce narrower limits of stability (14, 34). For high flow blockage ratios we expect to obtain excessively high local flow velocities and wake interference.[6]

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[6] In this connection see also M. Ames, AE thesis, California Institute of Technology, Pasadena, June 1956.

An increase in the number of flame-holders for flow through a duct of given size reduces the distance required for complete burning. This phenomenon is of considerable practical importance in ramjet design. If one assumes that there is no interaction between the separate flame stabilizers and that the angle of flame-spreading is the same as for a single bluff body in a duct, then the distance required for complete burning should be inversely proportional to the number of flame-holders. In other words, in the absence of interaction, one would expect the chamber length necessary for complete combustion to be proportional to the flame-stabilizer separation distance. Measurements (14) with 2, 4, and 8 rod flame-holders in a rectangular duct have, however, indicated that the flame length varies roughly as the two-thirds power of the separation distance, presumably because of interaction phenomena.

The three principal features of a flame-holder, which determine its suitability for engine applications, are: the rate of flame spreading, the flame-holder drag, and the region of flame stability (34, 35). Tests on single bluff bodies have shown that, for a given combustion chamber, the widest stability limits and lowest rates of flame spreading (i.e., lowest combustion efficiencies) are obtained with a single central baffle flame-holder. A grid-type flame-holder, on the other hand, has high combustion efficiency but relatively narrow stability limits. A reasonable compromise between these two designs is an annular baffle flame-holder (34). The flame-holder drag is determined largely by aerodynamic effects. Since streamlined bodies have low drag but narrow stability limits and bluff bodies have large drag and wide stability limits, a compromise must also be made between low drag and wide stability limits.

IV. THEORETICAL STUDIES OF FLAME STABILIZATION

The published theoretical studies on flame stabilization deal with bluff-body flame-holders. We shall survey these investigations in Section IV A. Furthermore, since useful correlations can be obtained for blowoff studies with reverse fluid jets, we conclude (Section IV B) the discussion with a critical evaluation of experimental results in terms of the simplified model for the critical flame-holding region which was mentioned in Section III B.

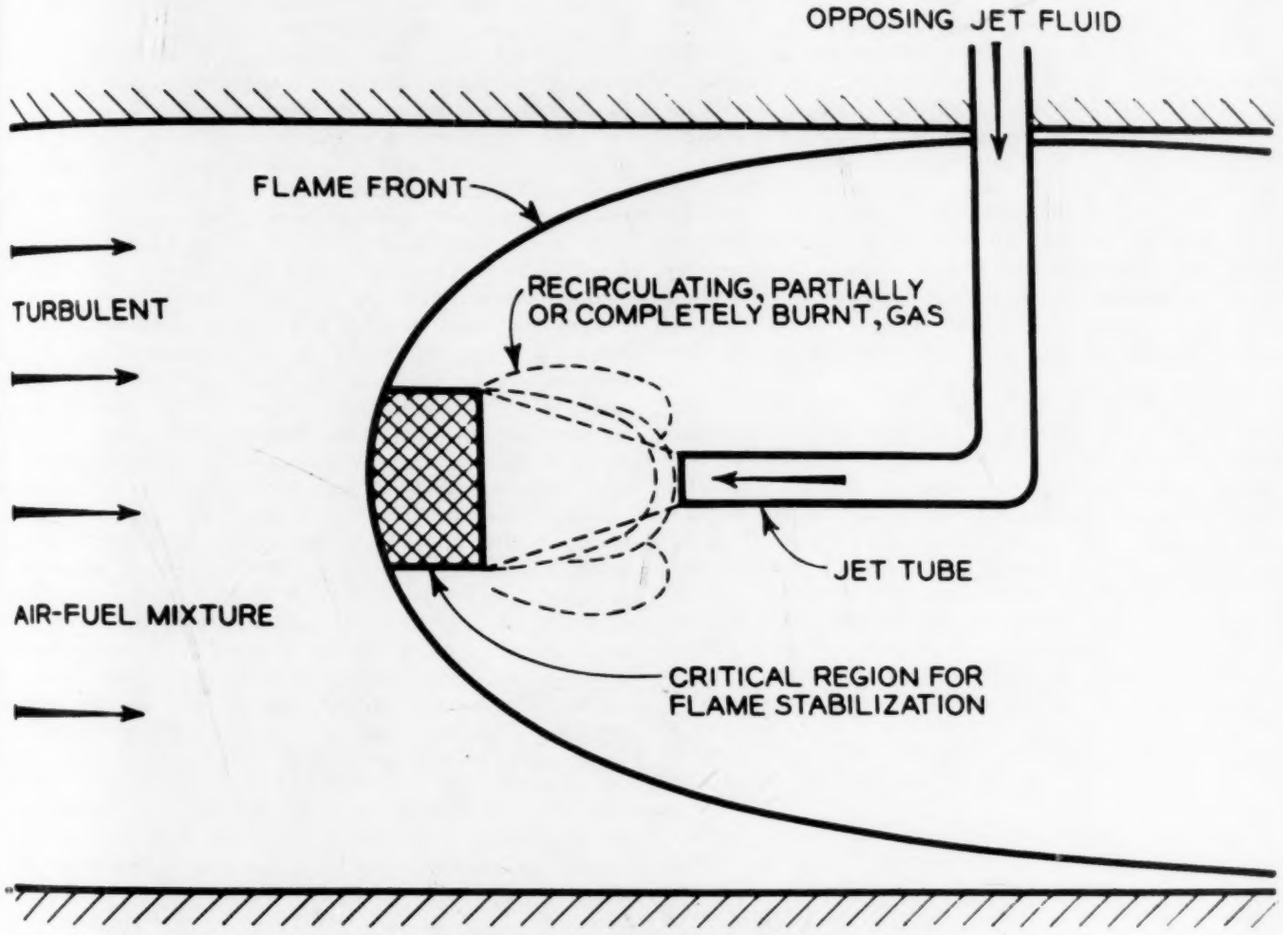

FIG. 2. SCHEMATIC DIAGRAM OF THE OPPOSING JET FLAME HOLDER

A. Bluff-Body Flame-Holders

The proposed theoretical models for flame holding appear, at first sight, to be very different. The assumed mechanisms range from instantaneous mixing with chemical reaction as the rate-controlling step to instantaneous reaction with mass or

heat transfer as the important step. Also the geometric configuration in the flame-holding process has been idealized to one involving either transport phenomena oriented axially or normal to the tube axis. Nevertheless, the predicted variation of blowoff velocity with pressure and flame-holder dimension turns out to be practically the same in all cases and to be in accord with observations. For this reason the significance of any given model must be interpreted in terms of the validity of detailed assumptions relating to the known properties of the stabilization process (see Fig. 1 and the discussion in Section II).

1. The Stirred Reactor Model

Longwell et al. (36) assumed that the recirculation region may be approximated as a homogeneous, stirred, chemical reactor. Flame stabilization is then supposed to be determined by a balance between the rate of flow of unburned gases into the recirculation zone and the rate of burning of these gases. In the case of a second-order chemical reaction, it turns out that the mass flow into the recirculation zone at blowoff is directly proportional to both the volume of the recirculation zone and to the square of the pressure. For a given equivalence ratio, as the mass flow into the recirculation zone is increased, the combustion efficiency drops until the gas residence time in the homogeneous reactor (recirculation zone) becomes too short to maintain combustion, and blowoff occurs. The range of equivalence ratios over which a flame can be stabilized is found to depend on the parameter VP^2/m where V is the volume of the recirculation zone, P equals the pressure, and m represents the mass flow into the recirculation zone.

The volume of the recirculation zone should be approximately proportional to the square or cube of the characteristic dimension of the flame-holder for a two- or three-dimensional bluff-body, respectively. If it is assumed that the mass flow m is directly proportional to the flow velocity, density or pressure, and to some power of the flame-holder diameter, then it is found that the blowoff velocity varies linearly with the pressure and with a power of the flame-holder characteristic dimension. In order to obtain agreement with the experiments of De Zubay (17), it is necessary to assume that m is proportional to the 2.15-power of the flame-holder diameter. A curve of the dependence of blowoff velocity on equivalence ratio, which agrees approximately with the experimental results of De Zubay, may be derived by using reasonable estimates for the recirculation zone volume and for the over-all chemical reaction rate.

The postulate of flame holding by a homogeneous reactor implies that the temperature in the reactor (i.e., in the recirculation zone) is the adiabatic flame temperature if small corrections caused by heat losses are neglected. Hence, as blowoff is approached, the combustion efficiency and the temperature of the recirculation zone should both decrease. These last conclusions are contrary to the observations that the temperature in the recirculation zone (3) and the combustion efficiency (2) remain practically constant as blowoff is approached. Furthermore, on the basis of the detailed results discussed in Section II and summarized in Fig. 1 it appears, in fact, that the bulk of the chemical reactions do not occur in the recirculation zone. Thus, although the stirred reactor model can be used to correlate empirical data, it is unlikely that it provides a valid description of the mechanism of flame holding.

2. Models Depending on a Balance Between Turbulent Mass and/or Heat Transfer and Energy Absorption by Cool Gases

Several investigators have proposed that the balance between turbulent mass and/or heat transfer and energy absorption by cool gases determines the critical conditions for blowoff. The detailed description of the wake geometry is inconsequential for this analysis.

De Zubay (17) assumed that two recirculating elliptic toroids in the wake of the disk serve as a pilot zone for maintaining a stable flame. Unburnt gas enters the pilot zone by turbulent diffusion while the burnt gas is lost downstream at an appropriate rate. Study of De Zubay's analysis shows that the critical conditions for blowoff are assumed to be determined by a balance between the rates of heat liberation in the toroid by chemical reaction and the rates of heat absorption by unburnt gas entering the toroid at an effective ignition temperature. According to Prandtl's hypothesis, the turbulent heat transfer coefficient is equated to the square of a mixing length multiplied by the absolute value of the velocity gradient and by the temperature gradient. Introduction of a variety of additional approximations (e.g., the temperature gradient equals the ratio of the difference between the burnt gas and ignition temperatures to the flame thickness; the mixing length is proportional to the product of downstream distance and a power of the Reynolds number; the flame thickness is proportional to the quenching distance which, in turn, varies as the 0.9 power of the pressure (37); etc.) then leads to a theoretical relation which is of the same functional form as the expression used for empirical correlation of data. The toroidal recirculation eddy represents a poor approximation to the true state of affairs, as is evident from the detailed discussion of wake behavior given in Section II.

Lees (38) has developed a model for flame stabilization on the basis of the hypothesis that, at sufficiently high Reynolds numbers, the wake flow becomes fully turbulent. Although this theory predicts correctly the dependence of blowoff velocity on flame-holder diameter for turbulent wake flow, the details of the model are also not in accord with the structure of the wake zone deduced in Section II. In Lees' "wake-mixing model," flame stabilization is assumed to involve turbulent transport of some of the unburnt gas across the wake boundaries. This gas is then heated to an ignition temperature by turbulent heat conduction. At the blowoff conditions, the rates of heat liberation by chemical reaction in the wake and the rates of energy absorption for heating of the cold gases to a critical ignition temperature are just equal. Under these conditions, the approach stream velocity may be identified with the blowoff velocity and turns out to be proportional to the flame-holder breadth as well as to the square of the normal turbulent burning velocity while it varies inversely with the turbulent mass-transfer coefficient. Basic to the analysis is the statement that the mass flux in the wake is a linear function of the mass flow of the approach stream with the proportionality constant equal to the turbulent mass-transport coefficient (39).

Except for an assumed change in the wake geometry and the use of a somewhat different approximation for turbulent mixing, Lees' theory and results resemble those of De Zubay in so far as the postulated flame-holding mechanism is concerned. The geometries of the two models are opposite in that Lees assumes axial heat transfer and De Zubay assumes mostly heat transfer in a direction normal to the wake axis.

Another closely related model is one of three suggestions made by Spalding (40). This author considers flame holding by two standing vortices behind a bluff body with the critical condition for blowoff corresponding to the requirement that the heat evolved by chemical reaction in the vortices equals the heat lost downstream by turbulent heat conduction. Setting the latter proportional to $V_{BO}PD$ where D is the diameter of the flame-holder, P equals the pressure, and V_{BO} is the blowoff velocity, and stating that the critical size of the vortex

equals roughly double the size of a hot gas pocket which just supports combustion, Spalding arrives at the relation

$$V_{BO} \sim DP\,Su^2 \qquad [2]$$

where Su is the laminar burning velocity. Except for the occurrence of the laminar instead of the turbulent burning velocity, Spalding's early result is seen to be identical with that of Lees.

4. Models Involving the Balance Between Convection and Chemical Times

Spalding (40) has also suggested that the critical condition for flame stabilization may correspond to the requirement that the chemical heat release rate multiplied by the contact time between the combustible and hot gases has a fixed lower limit. The critical contact time is then set proportional[7] to D/V_{BO}, whereas the chemical heat release rate is identified with the heat release rate in the premixed undiluted combustible gas. The stated conditions lead again to Eq. [2] for any order of the chemical reaction.

The correlation expressed by Eq. [1] also involves the idea that a critical minimum time is required for the combustible fluid to pass through the wake zone. The model implicit in the theory of Spalding (40) and in the correlation of Zukoski and Marble (3) is consistent with the physical picture sketched in Fig. 1. However, since it does not involve the flame-spreading pattern downstream of the recirculation zone, it is essentially incomplete.

B. *Reverse-Jet Flame-Holders*

As was pointed out in Section III D, the drag of a flame-holder is an important performance parameter. For this reason it is of interest to compare the drag at blowoff for reverse-jet flame-holders and for baffle-type flame-holders. Experimental results show that the drag force at blowoff varies as the fourth power of the blowoff velocity for both types of flame-holders with nearly the same constant of proportionality (41). The result that a minimum drag force is necessary to hold a flame by either technique suggests that the mechanism of flame holding may also be similar in the two cases.

1. General Remarks Relating to Reverse-Jet Flame-Holders

The detailed flame-holding mechanism for the opposing-jet flame-holder has not been worked out, although it appears likely that the concept of a critical region, with composition determined by the combustible mixture and the reverse fluid jet, forms a useful first approximation (compare Section III B).

In this connection some preliminary experiments by E. Pohlmann on the effect of jet velocity (or jet supply pressure for fixed jet-tube diameter) are of interest (31). These studies have shown that the blowoff velocity increases with increasing relative velocity between the primary gas mixture and the jet stream. Thus the stabilization mechanism must be intimately tied up with the mixing processes between the combustible mixture and the partially or completely burnt gases entering through the recirculation zone.

2. Correlation of Reverse-Jet Flame-Holder Data

We proceed now to describe a useful method for correlating some of the performance results of reverse-jet flame-holders. Following the implications of the experimental data considered in Section III B, we shall assume that the approach flow in the duct and the jet fluid mix in the flame-holding region in such a way that, at the maximum value of the blowoff velocity V_{BO} as a function of approach stream equivalence ratio φ, the local equivalence ratio in the flame-holding region $\varphi \equiv b$ is a constant characteristic of the air-fuel mixture. Here the equivalence ratio is defined in the usual way as the mass ratio of fuel to air divided by the stoichiometric fuel-to-air mass ratio s.

Let A_j and F_j denote the mass flow rates in the reverse jet of air and fuel, respectively. Also let A_a and F_a represent the corresponding mass flow rates in the duct. Then we define the following dimensionless parameters:

$$\beta = \frac{A_j + F_j}{A_a + F_a} \text{ in the flame-holding region,} \qquad [3]$$

$$\gamma = \frac{F_j}{A_j}, \qquad [4]$$

$$\varphi = \frac{F_a/A_a}{(F_a/A_a)_{\text{stoichiometric}}} \equiv (1/s)F_a/A_a. \qquad [5]$$

Replacing F_j and F_a in Eq. [3] by the use of Eqs. [4] and [5] leads to the result

$$\beta = \frac{A_j(1+\gamma)}{A_a(1+\varphi s)}. \qquad [6]$$

Furthermore, according to our basic assumption, the local value of φ in the critical flame-holding region for the largest blowoff velocity is defined by

$$b = \frac{(F_a + F_j)/(A_a + A_j)}{s} = \frac{(A_a s\varphi + \gamma A_j)/(A_a + A_j)}{s}. \qquad [7]$$

From Eqs. [6] and [7] we now find that

$$\beta = \frac{s(b-\varphi)}{\left(\frac{\gamma - bs}{1+\gamma}\right)(1+\varphi s)}. \qquad [8]$$

For a pure air jet, $\gamma = 0$ and Eq. [8] reduces to

$$\beta = \frac{\varphi - b}{b(1+\varphi s)}. \qquad [9]$$

For an approach flow consisting of natural gas and air, we find $s = 0.0555$; from the measured values (32) of V_{BO} as a function of φ it appears that $b = 0.9$. But for stabilization by a pure air jet ($\gamma = 0$) the maximum value of V_{BO} occurs (32) for $\varphi = 1.4$. Hence we find from Eq. [9] that $\beta = 0.50$. Similarly, for an air-fuel jet with $\gamma = 1.67$ it has been found (32) that $\varphi = 0.58$. Therefore, from Eq. [8], $\beta = 0.44$. In other words, for identical fluid-dynamical arrangements in which only the composition of the jet is varied, our postulate concerning the value of b shows that the relative contribution of the jet stream to the gas in the flame-holding region, β, is practically constant, as would be expected for tests in which the mixing pattern remains unchanged.

Cambel et al. (30, 31) have obtained a value of $\beta = 0.41$ for

[7] This statement is equivalent to the statement that the chemical conversion time varies as the ratio of wake length L to blowoff velocity since the ratio L/D is practically constant for turbulent wakes and is independent of the relevant Reynolds number (3).

propane-air mixtures with a slightly different geometric arrangement and higher jet pressure (70 psig compared with 15 psig) than were used in the natural gas-air studies. This result suggests that β is relatively insensitive to pressure, a conclusion which is also consistent with the observation that b is insensitive to changes in jet pressure for otherwise fixed arrangements.

The available experimental data suggest either that the absolute maximum value of V_{BO} is a linear function of jet pressure (30, 31) or else varies with the square root of the jet pressure (32). The data leading to the former conclusion look more convincing.

Variations in jet diameter change the value of φ for which V_{BO} is a maximum. For the natural gas-air data the results are roughly correlated by the assumption that β is proportional to the jet diameter under otherwise constant conditions.

The temperature of the jet fluid has a large effect on stability. In a typical case, increasing the jet temperature from 70 F to 1030 F at constant manifold pressure increased the maximum blowoff velocity from 230 ft/sec to 310 ft/sec even though the mass flow rate through the jet decreased. For the same jet mass flow rate, increasing the jet temperature from 70 F to 1030 F increased the blowoff velocity by nearly a factor of three.

The preceding summary statements of reverse-jet performance are too sketchy to form the basis for an adequate theoretical discussion. However, the importance of the local mixture composition in the flame-holding region appears to have been demonstrated. It appears now to be desirable to perform detailed studies on the critical region in order to elucidate the physical changes and mixing processes involved in flame holding.

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"Letters to the Editor" and "Books Received for Review" appear after the reviews

Theoretical and Experimental Methods

(See also Revs. 1688, 1695, 1727, 1740, 1775, 1776, 1821, 1825, 1830, 1832, 1908, 1945, 1978, 1983)

1660. Prager, W., A generalization of Hitchcock's transportation problem, Brown Univ., Div. appl. Math. IBM-16, 14 pp., June 1956.

Paper deals with the problem of flow of a homogeneous product from production centers through routes to consumption centers. The assumptions are: (1) Steady, nonnegative flow not exceeding route capacity; (2) known cost of maintaining a unit flow rate for each route; (3) constant rate of production or consumption for each center, equal to the total amount shipped from or received at that center; (4) constant price per unit of product at each center; (5) the price differential between both ends of each route is not larger than, equal to, or not smaller than the shipping cost for this route according to whether the route carries zero flow, nonvanishing flow below capacity, or capacity flow.

The problem considered is: given either the price or rate of production or consumption at each center, to determine the other prices and rates at the centers and the flow rates for the routes in accordance with the above assumptions and conditions.

Author establishes that if any solution exists, either it is unique, or any alternative solution should have the same unused and capacity-used routes, the difference being only in the non-zero below capacity routes. He also shows some minimum and maximum characterizations of the solutions.

This method has the advantage of simplicity. It can be applied to such engineering problems as the distribution of products over machines. M. Dessouky, USA

1661. Douglas, J., Jr., The solution of the diffusion equation by a high order correct difference equation, *J. Math. Phys.* **35**, 2, 145–151, July 1956.

Author derives a second-order difference equation for the numerical solution of a boundary-value problem for the diffusion equation. The procedure is implicit and stable for any size time step. Author shows that the solution of the difference equation converges uniformly to the solution of the continuous problem provided that solution exists and has suitable differentiability properties. The rate of convergence is shown to be greater than that for previously known implicit methods. Since the computational effort required to solve the linear equations arising at each step will be about the same as for other implicit methods, the increased convergence rate makes the author's procedure a highly attractive vehicle for numerical work. M. Stein, USA

1662. von Holdt, R. E., An iterative procedure for the calculation of the eigenvalues and eigenvectors of a real symmetric matrix, *J. Assn. Comp. Machy.* **3**, 3, 223–238, July 1956.

Method is a variant of gradient method of Hestenes and Karush ["Matrix calculus," E. Bodewig, Interscience Publishers, 1956, p. 294], but here the first eigenvalue to be found need not be the greatest nor least. Each stage of the iteration requires the construction of a matrix, some matrix multiplications, and the solution of a set of linear equations. In spite of this, author believes that method compares favorably with gradient method because only a few iterations are needed for convergence. It has been programmed for I.B.M. 701 computer at Los Alamos, where, for matrixes up to order 16, less than 5 iterations per eigenvalue were required on the average.

Reviewer feels that a more valuable comparison would be with the Jacobi method. It also is independent of the closeness of spacing of the eigenvalues, it is simple to program, and has been found extremely useful on symmetric matrixes when all the roots are wanted. C. C. Gotlieb, Canada

1663. Downing, A. C., Jr., and Householder, A. S., Some inverse characteristic value problems, *J. Assn. Comp. Machy.* **3,** 3, 203–207, July 1956.

Problems inverse to that of finding the characteristic roots of matrixes are discussed. These are: given a Hermitian matrix A, find (1) a real non-singular diagonal matrix D such that $|A - \lambda D^2|$ has prescribed roots (or, alternatively, such that the Hermitian matrix $D^{-1}AD^{-1}$ has prescribed characteristic roots), and (2) a real diagonal matrix D such that $A + D$ has prescribed characteristic roots. Criteria for the existence of solutions are not known but, assuming that solutions do exist, iterative methods are presented for improving an approximate solution D_0. Each stage of the iteration requires the determination of the characteristic roots and vectors of $D_0^{-1}AD_0^{-1}$ (or $A + D_0$) and the solution of a set of linear equations. In general the iteration is of second order and therefore rapidly convergent. A connection between the two problems is established, and a generalized problem stated, with an outline of the solution. C. C. Gotlieb, Canada

1664. Clenshaw, C. W., The numerical solution of linear differential equations in Chebyshev series, *Proc. Camb. phil. Soc.* **53,** 1, 134–149, Jan. 1957.

Given a linear differential equation with rational coefficients, idea is to assume an expansion in Chebyshev polynomials for the first kind for the highest derivative. Now integrals of these polynomials are polynomials of the same type. Further, any power of x multiplied by a Chebyshev polynomial may be expressed as a sum of Chebyshev polynomials. Utilizing these facts leads to recurrence relations for determination of the coefficients. Several examples are presented. Comparison is made with the τ-method introduced by C. Lanczos. [See e.g., "Tables of Chebyshev polynomials $S_n(x)$ and $C_n(x)$," *Nat. Bur. Stands., Appl. Math. Ser.* no. 9, 1952]. Y. L. Luke, USA

1665. Bolton, H. C., and Scoins, H. I., Eigenvalue problems treated by finite-difference methods, *Proc. Camb. phil. Soc.* **53,** 1, 150–161, Jan. 1957.

This is a continuation of a previous article [AMR **9,** Rev. 3821]. Using finite difference techniques, it is shown that the two-dimensional Schroedinger equation $H\psi = \lambda\psi$ can be expressed in matrix form $A\mu = \lambda\mu$. Results of calculations for two electrons in a sphere are presented. Application to the helium atom is discussed. Y. L. Luke, USA

Book—1666. Giet, A., Abacs or nomograms, London, Iliffe & Sons Ltd.; New York, Philosophical Library, Inc., 1956, ix + 225 pp. $12.

Aside from being on page one in a dictionary, the term "abac" as a synonym for "nomogram" has little else to recommend it. To American readers, this British translation of a French work has similar linguistic obstacles throughout. Most of the illustrative nomograms are worthless for immediate use because of their metric scales. Some of the nonmetric ones are more clumsy than identical-purpose nomograms published in American trade literature; e.g., compare Giet's worm-gearing efficiency nomogram, Fig. 110 on p. 162, which requires two drawn lines, with reviewer's Fig. 6 on p. 156 of August 1951 *Prod. Engng.* [**22,** no. 8] requiring one line only.

The chapter on circular nomograms suffers in comparison with a similar chapter in Douglass and Adams' "Elements of nomography" [McGraw-Hill, 1947] because the practical use of an auxiliary scale along a tangent line is not mentioned by Giet and there are only three figures in the chapter compared with seven figures in the American text.

The avowed purpose of the book is to assist engineers in making nomograms of their own, yet several electrical and mechanical engineers in the reviewer's company have stated preferences for American books at half the sales price.

E. C. Varnum, USA

1667. Slibar, A., Graphic-numerical integration of a system of simultaneous ordinary nonlinear differential equations of the second order (in German), *Ost. Ing.-Arch.* **10,** 2/3, 288–291, 1956.

As the title indicates, paper deals with systems of equations of the form $\ddot{x}_i = u_i(\dot{x}_k, x_k, t)$ for $i, k = 1, \ldots, n$, which describe, e.g., a vibrational system of n mass points. A stepwise solution method is described in which, at each step, the values of $\ddot{x}_k$, $\dot{x}_k$, x_k and t are determined graphically while the corresponding values u_i are calculated numerically. The method is a generalization of one described by E. Braun in 1937 for a single equation and seems to represent a slight improvement over the "phase-plane-delta" method described by L. S. Jacobsen [*J. appl. Mech.* 1953]. Author recommends in a concluding remark that, when possible, the calculation of the functions u be done in advance of the integration, by tabulating and graphing them for the whole domain likely to be needed. It seems to this reviewer that advance tabulation and graphing of functions of several variables is impractical except in very special cases, though the latter may well occur frequently in applications. F. L. Alt, USA

1668. Welanetz, L. F., Graphical versus computer techniques—for mechanism analysis, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-48, 6 pp.

Kinematic analyses of a spring-driven shutter linkage mechanism were made, both by the conventional graphical procedure and by the use of an automatic digital computing machine. A description is given of the general method of solution which involves the use of the principle of work and kinetic energy. A comparison is made of the two procedures with regard to accuracy and time required. Results of the calculations are shown in graphical form.

From author's summary

1669. White, J. C., Computers as design tools, *Mach. Design* **29,** 2, 83–87, Jan. 1957.

1670. Fisher, M. E., Higher order differences in the analogue solution of partial differential equations, *J. Assn. Comp. Machy.* **3,** 4, 325–347, Oct. 1956.

In applying differential analyzers to partial differential equations with two independent variables, the continuous increase of one of these variables is replaced by discrete increments, usually of equal amount. The original equation is accordingly transformed into a set of simultaneous difference equations. The error due to this procedure can, in principle, be reduced by diminishing the increments; in computing practice this reduction is restricted by

the available time and the available equipment. With a given value of the increments, the accuracy can still be increased by using differences of higher orders. In this case there exist, however, ("spurious") solutions of the difference equations which do not solve the original differential equation. In the present paper, methods are developed by which the appearance of the spurious solutions, or at least the error caused by these solutions, is avoided. By way of general deductions and specific examples it is shown which type of problems can profitably be solved by higher-order difference equations.

R. Eisenschitz, England

1671. Cahn, C. R., Solution of algebraic equations on an analog computer, *Rev. sci. Instrum.* **27,** 10, 856–858, Oct. 1956.

A method has been found for solving an algebraic equation for a real or complex root on an analog computer (electronic differential analyzer). The computer connections are arranged so that the root locations may be shifted along the real axis of the complex plane by adjusting a ganged potentiometer. A maintained transient is indication that a root has been shifted to the imaginary axis, allowing the real and imaginary parts of the root to be read. The accuracy is reduced when a second nearby root is present; however, poor tracking in the ganged potentiometer has about the same effect as an improper setting of a coefficient of the equation.

From author's summary by C. B. Ludwig, USA

1672. Martin, H., The range of trustworthiness of the variation coefficient, an important value regarding statistical calculations (in German), *Faserforsch. u. Textiltech.* **7,** 9, 413–417, Sept. 1956.

1673. Daniel, C., Application of statistical methods in chemical engineering, *Indust. Engng. Chem.* **48,** 9, 1392–1402, Sept. 1956.

1674. Swensson, T., Computations in engineering and science with the help of the rationalized MKSA system, *Forskn. Tekn.* no. 1, 51 pp., 1953.

Mechanics (Dynamics, Statics, Kinematics)

(See also Revs. 1696, 1698, 1710, 1788)

1675. Kozhevnikov, S. N., and Tsekhinovich, L. I., Mechanical linkages with prescribed relative motion of the movable links (in Russian), *Trudi Sem. teor. masb. mekh. in-ta mashinoved, Akad. Nauk USSR* **14,** 56, 59–89, 1955; Rev. no. 696, *Ref. Zb. Mekh.* 1956.

An analysis of two-dimensional mechanical systems, with prescribed relative motion of two hinged, movable links. The positions of the links are determined by "eliminating" the hinge, or by substituted joints: the first method being applicable when elimination of the hinge enables the mechanism to be resolved into two kinematic linkages in which the center point of the eliminated hinge travels in prescribed paths. The required position of the hinge is found at one of the points of intersection of the said paths. In the second method, links in prescribed relative positions are assumed to be rigidly connected and the length of any particular link to be variable. In such case, by changing the configuration of the system and "substituting" joints, the position of the links can be found, in which the variable lengths thereof coincide with the actual lengths. It is suggested for the determination of the velocities and accelerations in the system to use vectorial equations, which can be derived if, for the links the relative motion of which is to be determined, the known relationships between velocities and accelerations in absolute, relative, or derived motion are applied. A method of graphical analysis of the solutions of these equations is described for particular mechanical systems. It is further shown that determination of the positions, velocities and accelerations, can be performed by inversion (reversal of motion); i.e., by examining the motions of all links relatively to one of the movable links, the relative motion of which is prescribed. The application of this inversion method is demonstrated on an example of the kinematic analysis of the walking motion of an excavator.

N. I. Levitskii, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1676. Tamamshev, A. A., On the calculation of the forces in a mechanism with links of variable dimensions (in Russian), *Gruz. Polytech. Inst.* no. 34, 97–101, 1954; Rev. no. 695, *Ref. Zh. Mekh.* 1956.

The case is examined of a quintuple-hinged linkage representing a system with two degrees of freedom. It is pointed out that the kinetic analysis of this system can be performed by the usual methods of the kinetostatics of mechanisms with one degree of freedom if, at any instant of time, one of the kinematic couples becomes a rigid connection; i.e., the quintuply-hinged system becomes one with four hinged links.

Courtesy of Referativnyi Zhurnal N. I. Levitskii, USSR
Translation, courtesy Ministry of Supply, England

1677. Satterly, J., Moments of inertia of solid rectangular parallelopipeds, cubes, and twin cubes, and two other regular polyhedra, *Amer. J. Phys.* **25,** 2, 70–78, Feb. 1957.

1678. Sergeev, V. I., On the investigation of errors in cam profiles (in Russian), *Trudi Semin. tochnosti mekh. i mash.-in-ta mashinoved, Akad. Nauk USSR* no. 7, 73–82, 1954; Rev. no. 699, *Ref. Zh. Mekh.* 1956.

The results are given of a statistical evaluation of the errors in a batch of disk cams by mass-production methods in a copy miller. The profile errors were measured from the equidistant to the profile by a Zeiss microscope. The theoretical distribution of the errors is assumed to be Gaussian.

It is recommended to abandon 100% inspection of the profiles in a number of positions (by angle of rotation) and resort to batch tests in selected positions, if the statistical characteristic of the batch in question satisfies the mathematical expectation and the root mean square $\sigma\,|\Delta p| \approx \text{const}$.

Analysis and recommendations are made for the conditions of the steady-state process in regard to cam errors, and for certain other applications of the theory of accuracy.

Courtesy of Referativnyi Zhurnal D. M. Lukichev, USSR
Translation, courtesy Ministry of Supply, England

1679. Johnson, R. C., How profile errors affect cam dynamics, *Mach. Design* **29,** 3, 105–108, Feb. 1957.

1680. Dimentberg, F. M., Stability of flexible shafts with unbalanced disks subjected to the effect of internal and external friction (in Russian), *Izv. Akad. Nauk SSSR, Otd. tekh. Nauk* no. 10, 75–86, Oct. 1954.

1681. Swyngedauw, M. R., A general law for the slip of flat and V-belts, Part I (in French), *Mem. Soç. Ing. civ. Fr.* **119,** 4, 312–315, July/Aug. 1956.

Paper gives a relation between the slip of a belt and the location of the "neutral layer" in the belt, defined as the layer which does not alter velocity by transition from rectilinear movement (between the pulleys) to the movement in curve (at the entrance on the pulley). If site of said layer is given (i.e., is measured by experiments) then the slip may be found by author's formula. Reviewer believes author's most interesting statement to be a predic-

tion of negative slip by a given belt, an unexpected consequence which was confirmed by subsequent experiment.

A. R. Holm, Denmark

1682. Cole, H. A., Jr., and Bennion, F. L., Measurement of the longitudinal moment of inertia of a flexible airplane, *NACA TN* 3870, 30 pp., Nov. 1956.

Paper presents analysis of methods for minimizing flexibility effects, and evaluates results as applied to typical airplane. Authors first derive approximate dynamic equations for airplane and measurement support system, then discuss measurement techniques for minimization of flexibility effects. Techniques include, first, uncoupling of wing first-bending mode by proper selection of spring location and, second, maintaining small flexibility effects by using small oscillation frequency.

Three arrangements of spring and knife-edge locations demonstrating former technique are compared with rigid-airframe calculations for typical airplane. Results provide choice of best (i.e., smallest deviation from rigid-body values) arrangement for airplane.

Analysis of latter technique indicates airplane oscillation frequencies greater than 50% of wing first-bending-mode frequency introduce sizeable flexibility errors in moment-of-inertia measurements.

Description of longitudinal moment-of-inertia measurement is given, including data on, and methods of, necessary corrections.

Reviewer believes paper presents excellent basis from which engineers may develop measurement arrangements peculiar to particular airframes. H. L. Bloom, USA

1683. Slater, J. M., Measurement and integration of acceleration in inertial navigation, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-160, 10 pp. + 4 figs.

Measurement and integration of acceleration in inertial navigation is associated with instrumentation problems of a character different from those in other fields of technology. The purpose of paper is to outline the principles of such measurements, and some typical approaches to instrumentation.

From author's summary

1684. Blitzer, L., Weisfeld, M., and Wheelon, A. D., Perturbations of a satellite's orbit due to the earth's oblateness, *J. appl. Phys.* **27**, 10, 1141–1149, Oct. 1956.

Motion of artificial earth satellite is discussed for free-flight conditions (after rocket burn-out) with neglect of atmospheric drag. Three-dimensional treatment in inertial frame is given for spherical and oblate earth; oblateness is represented by quadrupole field in latter case. Salient results are analytic formulas for regression of orbit nodes and corresponding radial oscillation in a nearly circular orbit (near earth's equatorial plane). Authors conclude that radar determination of the nodal regression can yield value, exceeding by 2.5 the present accuracy, for the ratio of coefficients of second to zeroth-order harmonics in expansion of earth's gravitational potential, since retrograde motion in inertial space can amount to forty miles per revolution. Radar inaccuracies make difficult a precise determination of earth's radius or product of its mass by gravitational constant.

Appendixes discuss effect of atmospheric drag and possible precision in fixing burn-out velocity. In a recent letter [L. Blitzer and A. D. Wheelon, *J. appl. Phys.* **28**, p. 279, 1956], it is concluded that burn-out parameters of satellite probably cannot be controlled accurately enough to obtain circular orbit, and results are generalized to elliptic orbit. J. J. Gilvarry, USA

1685. Vernotte, P., Contribution to the direct measurement of gravitational acceleration (in French), *C. R. Acad. Sci. Paris* **243**, 3, 227–229, July 1956.

1686. Apps, D. C., and Vanator, G. M., Tire thump: its mechanism and measurement, *SAE Trans.* **63**, 787–802, 1955.

1687. Ishlinsky, D. Yu., On the sliding motion of dynamic systems (in Ukrainian), *Prikl. Mekh.* **1**, 1, 51–66, 1955; Rev. no. 653, *Ref. Zh. Mekh.* 1956.

Dynamic systems are examined, described by equations of the following form

$$\frac{dx_k}{dt} = X_k(x_1, \ldots, x_n) \qquad [1]$$

where $k = 1, \ldots n$; the function X_k has discontinuities of the first kind on certain surfaces F_j. From geometrical considerations, it is assumed that the phase point P either jumps through the particular discontinuity plane or remains therein, performing so-called sliding motion with a lesser number of independent coordinates. In the investigation of sliding states, it is assumed that the function X_k in Eq. [1] is the limit of the continuous function X_k^* everywhere coinciding with X_k except in the narrow bands adjacent to the discontinuity plane F_j. An example is given of a gyroscopic system, described by an equation of the following form

$$\frac{dx}{d\tau} = x + y - m(x); \quad \frac{dy}{dx} = -(x + y)$$

with a discontinuity function $m(x) = m$ sign x.

Courtesy of Referativnyi Zhurnal A. N. Obmorshev, USSR
Translation, courtesy Ministry of Supply, England

1688. Pozharitskii, G. K., On the characteristic number of the vanishing solution of the equations of perturbed motion (in Russian), *Prikl. Mat. Mekh.* **19**, 4, 481–484, July/Aug. 1955.

Consider a vector equation: [1] $y' = f(t, y)$, where f is a vector function of real t and the point y, and let $y(t)$ be a particular solution of [1]. Let the corresponding perturbed vector equation be: [2] $x' = A(t)x + F(t, x)$, where $A(t)$ is a square matrix of real, bounded continuous functions, and F is analytic in x for each t and such that $F(t, x) = 0(|x|^2)$ for small $|x|$. Author shows that the characteristic number of the vanishing solution $x(t)$ of [2] is equal to one of the non-negative characteristic numbers of the linear equation: [3] $x' = A(t)x$. From this fact and certain theorems of Lyapunov and Chetayev on stability or instability of motion in the first approximation [3] author then deduces various simple consequences.

As an application, author discusses the question as to whether [1] can have two solutions $y_1(t)$ and $y_2(t)$ such that $|x| = |y_2 - y_1| \to 0$ as $t \to \infty$, and also the question of the stability of $y_2 = y_1 + x$ if x is a vanishing solution. In particular, he considers the problem of motion of a heavy rigid body about a fixed point, taking for $y_1(t)$ a permanent rotation and for $y_2(t)$ the classical V. A. Steklov solution. This discussion, however, is not complete.

E. Leimanis, Canada

1689. Schnitzer, E., Band-pass shock and vibration absorbers for application to aircraft landing gear, *NACA TN* 3803, 27 pp., Oct. 1956.

A new class of frequency-selective shock absorbers called band-pass shock absorbers, which were conceived as a means of overcoming some of the limitations of conventional shock absorbers, is described. These shock-absorber designs are introduced, special emphasis being given to their use in landing and taxiing problems of high-speed aircraft. For such aircraft operated on rough land or water runways, conventional oleo struts approach a rigid condition for bumps with steep slopes and thereby develop and transmit severe shock loads to the aircraft fuselage. The operation of the band-pass shock absorbers in the reduction of loads in certain selected frequency ranges is described. Theoreti-

cal equations are derived and solutions are made for several cases for the purpose of comparing the low-pass and conventional shock-absorber actions. The results indicate that the band-pass shock absorbers should alleviate high-frequency or rapidly applied impact loads but should retain the characteristics of conventional oleo struts when taxiing and design landing loads are slowly applied. A number of variations in design are presented for low-pass shock absorbers and reference is made to double-acting band-pass vibration absorbers for other applications.

From author's summary

1690. Leonov, M. Ya., and Chaievsky, M. I., Experimental verification of the steadiness of rotation of shafts in the transcritical region (in Russian), *Nauch. Zap. in-ta mashinoved. i. avtomatiki Akad. Nauk USSR* **4**, 3, 5–14, 1955; Rev. no. 675, *Ref. Zh. Mekh.* 1956.

A description of experiments on the investigation of the steadiness of rotation of shafts running at transcritical speeds (apparently, the steadiness of the precessional motion in relation to the rotational velocity is meant). For the case of cantilevered shafts with end disks, unsteadiness is found at all speeds above the critical. For shafts hinge-supported at the ends and with the disk in the center, stability depends on the ratio of "external" to "internal" friction. A determination is made of the damping decrement of the natural, flexural vibrations δ_1 for a shaft in the experimental arrangement, and the decrement δ_2 attached in such a manner as to reduce the "external" losses to a minimum. The following empirical relationship is established: if $\delta_1 - \delta_2 > \delta_2$ motion beyond the critical speed will be steady; if $\delta_1 - \delta_2 < \delta_2$, it will be unsteady. In the opinion of the author, these experiments contradict the known analytical solution, whereby the ratio between the forces of "internal" friction and the rates of deformation (distortion) is linear. V. V. Bolotin, USSR

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1691. Shekhvits, E. I., Analysis of the motion of the rotating mechanism of a multiple-spindle automatic machine (in Russian), *Issledovaniya v oblasti metallorezhushchikh stankov* no. 3, 114–133, 1955; Rev. no. 694, *Ref. Zh. Mekh.* 1956.

The laws of motion are analyzed and the active dynamic moments determined of the mechanism rotating the spindle head of an automatic machine tool by means of a four-tooth ratchet wheel (Geneva stop). The equation of motion of the mechanism is found by an approximation to the solution of an equation for an absolutely rigid linkage with the forces acting thereon determined by the speed and position of the links. For a closer approximation to the values of the dynamic moments thus found, the influence of elasticity of the shafting is investigated, but this part of the solution cannot be considered valid, since the approximations used are insufficiently motivated. The analytically calculated values of the dynamic moments are correlated with the values obtained experimentally. It should be noted that in order to reduce the dynamic forces while maintaining the speed of rotation of the mechanism, the crank of the ratchet wheel is most suitably driven by an elliptical gear train. A rotating mechanism of this type has been successfully used, e.g., in the Wickman automatic lathe, the 'Russian' PO-2 process block trimmer, etc.

Courtesy of Referativnyi Zhurnal F. L. Litvin, USSR
Translation, courtesy Ministry of Supply, England

1692. Dean, S. K., and Kilburn, M. A., Friction of steel slabs on a roller table under varying physical conditions, *Instn. mech. Engrs. Proc.* **169**, 54, 1081–1089, 1955.

Experimentally determined values of coefficient of friction between power-driven rolls and cold and hot steel slabs as in steel-mill transportations are presented. In reviewer's opinion these data should be useful to designers of such equipment.

Most tests were conducted under laboratory conditions designed to simulate mill conditions. A few results under actual mill conditions are also presented and are in good general agreement with the laboratory results.

The coefficient was found to vary with temperature, slab weight, and slipping velocity. Some unexplained variations are noted.

W. Schroeder, USA

1693. Henry, I. G., Lifetimes of artificial satellites of the earth, *Jet Propulsion* **27**, 1, 21–24, Jan. 1957.

The density of the upper atmosphere decays roughly exponentially with altitude. This variation is assumed to be exact, and the effect of the density is computed on the lifetimes of earth satellites in elliptical and in circular orbits. The physics of the drag is discussed. From author's summary

Servomechanisms, Governors, Gyroscopics

(See also Revs. 1707, 1711, 1863)

Book—1694. Oppelt, W., Short handbook of technical control processes, 2nd ed. [Kleines Handbuch Technischer Regelvorgänge, Zweite Auflage], Weinheim, Verlag Chemie, 1956, 555 pp.

This is the second, expanded (from 447 to 555 pages) edition of a popular German reference book on automatic control. A careful, page-by-page comparison with the first edition shows a very strong influence of current American control-systems technology, which accounts for almost all changes or additions in the text. These changes make the work much more readable to American- or English-trained engineers than was the first edition. Major new material is a detailed discussion of the root-locus method and a new (though still quite inadequate) chapter on nonlinear systems.

Printing is excellent and the quality of paper is much better than in the first edition.

The book is written on a level which is somewhat more elementary than standard introductory works in English. For instance, mathematical aspects of the Laplace transformation are avoided and frequency-response functions are dealt with in a heuristic but entirely adequate fashion. Examples are particularly abundant, especially those illustrating technological aspects of control systems. In keeping with the objectives of the book, there are also many standard curves and tables.

There is little original or new material. The book is highly recommended, however, as an unusually thorough and well-organized introduction to the fundamental aspects of control engineering.

R. E. Kalman, USA

1695. Bass, R. W., A generalization of the functional relation $Y(t + s) = Y(t) \cdot Y(s)$ to piecewise-linear differential equations, *Quart. appl. Math.* **14**, 4, 415–417 (Notes), Jan. 1957.

Author treats systems of ordinary linear differential equations with constant coefficients involving forcing functions which are step functions. These systems are characteristic of relay servomechanisms. A solution is given whereby one can compensate for a pure delay in the forcing functions.

R. Oldenburger, USA

1696. Sevin, E., Min-max solutions for the linear mass-spring system, ASME Ann. Meet., New York, N. Y., Nov. 1956, Pap. 56-A-26, 6 pp.

Object of paper is to determine minimum and maximum displacements of linear mass-spring system under forcing function having given value of total impulse (time integral of force) and given

duration. Maximum response occurs under instantaneous impact impulse. Conditions for minimum are more complex, and consist of initial and final impact impulses, which may (depending on parameters) be separated by an interval under constant force, over part of the given duration.

Phase plane technique is used, but paper is intelligible to readers of moderate mathematical ability without previous experience of this method. Paper is stated to have the object of gaining insight into the general problem of minimum and maximum responses of dynamical systems under forcing functions subject to boundary conditions.

The proof is based on highly ingenious reasoning; the whole paper is a fascinating exercise in applied mathematics, and a small masterpiece of its kind. R. Hadekel, England

1697. Schonsleben, M., "Beam rider" control of guided missiles, *Brown Boveri Rev.* **43,** 9, 393–398, Sept. 1956.

Among the many methods for controlling guided antiaircraft missiles, a prominent role is played by "beam riding." The manner in which it functions is briefly described, and the method of conveying the necessary information from the transmitter to the missiles discussed. From author's summary

1698. Abzug, M. J., Applications of matrix operators to the kinematics of airplane motion, *J. aero. Sci.* **23,** 7, 679–684, July 1956.

Matrixes are derived for transformation of coordinates between earth axes and aircraft body (stability) axes when the Euler angles are defined as by Durand. Result is applied to transformation of linear velocity, derivation of relationships between angular velocity components and rates of change of Euler angles, and to derivation of azimuth and elevation angles in earth axes and body axes for a line of sight having an arbitrary space orientation.

Transformation matrixes are also applied to the problem of analyzing gimbal angles of (1) conventional vertical gyro and (2) conventional directional gyro in the static case. Relations between aircraft attitude angles and gimbal angles are computed and shown on graphs for typical low-speed and high-speed conditions. Graphs show clearly the "gimbal errors" as well as regions of "gimbal lock."

First part of this work (transformation formulas) is contained in AMR **8,** Rev. 561 by Schulz and Ludwig.

K. Flodin, Sweden

Vibrations, Balancing

(See also Revs. 1689, 1718, 1720, 1746, 1787)

1699. Wittmeyer, H., A simple approximative calculation for bending frequencies of a cantilever beam with variable cross section and for eigenvalues of similar variational problems (in German), *ZAMM* **36,** 9/10, 355–367, Sept./Oct. 1956.

Eigenvalue problem for special self-adjoint differential equation of order $2n$ is solved approximately by considering corresponding variational problem. This problem is first transformed into canonical form and then replaced approximately by a one-parametric variational problem with constant coefficients. Value of parameter is determined such that exact value of smallest eigenvalue and its approximation are equal within a first-order perturbation expansion.

Exact eigenvalues of modified (i.e., one-parametric) problem can be calculated easily. They represent approximations to the lowest eigenvalue of original problem and, since eigenvalues of the two problems are asymptotically equal, also to corresponding higher eigenvalues. Approximation may, however, be poor in the medium range and should, in this reviewer's opinion, be replaced by a method similar to the one given above for the lowest eigenvalue. Author also indicates that some progress may be possible by using more than one parameter.

Case $n = 1$ corresponds to torsional vibrations of a bar treated previously by author [AMR **6,** Rev. 2693]. Case $n = 2$ represents bending vibrations of a cantilever beam with shearing force and rotatory inertia neglected. H. Parkus, Austria

1700. Ananiev, A. A., and Plodovitov, N. N., Experimental arrangement for studying the oscillations of supporting ropes (in Russian), *Tr. Leningr. politekhn. Inst.* no. 3, 9–16, 1954; Rev. no. 411, *Ref. Zh. Mekh.* 1956.

An experimental arrangement is described which models the transverse oscillation of a suspended rope. An example is examined of the choice of similarity conditions for the case of a perfectly elastic rope with attached ends, and a load concentrated in the middle of the span. V. G. Bessonov, USSR

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Translation, courtesy Ministry of Supply, England

1701. Chu, H. N., and Herrmann, G., Influence of large amplitudes on free flexural vibrations of rectangular elastic plates, *J. appl. Mech.* **23,** 4, 532–540, Dec. 1956.

Paper uses approximate perturbation procedure to find lowest natural frequency of vibration of rectangular elastic plate with hinged edges in which maximum amplitude is not small compared to thickness of plate. Results indicate that natural period decreases in parabolic manner for amplitude-to-thickness ratios less than 0.4, when the reduction is about 10%; for larger amplitudes decrease is nearly linear up to a ratio of unity, when the reduction is about 35%. Square plates have less reduction and narrow plates more reduction of period. Authors also apply their method to beam vibration and obtain results identical with those of Eringen.

N. O. Myklestad, USA

1702. Sharma, R. L., Dependence of the frequency spectrum of a circular disk on Poisson's ratio, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–10, 2 pp.

The results of computations of frequencies of axially symmetric flexural vibrations of circular disks are given for an intermediate frequency range and for several values of Poisson's ratio.

From author's summary

1703. Kaul, R. K., and Cadambe, V., The natural frequencies of thin skew plates, *Aero. Quart.* **7,** 4, 337–352, Nov. 1956.

Upper and lower bounds for the natural frequencies of thin skew plates are obtained by the Rayleigh-Ritz and Kato methods for plates with: (a) all edges clamped, (b) one edge clamped and three supported, and (c) two adjacent edges clamped and two supported. Deflection functions are taken as double series of tabulated normal beam functions.

Authors are apparently unaware of other work done by Young [AMR **4,** Rev. 1929] on rectangular plates, by Barton [AMR **4,** Rev. 4079] on skew cantilever plates, and by Dalley and Ripperger [AMR **5,** Rev. 2774] on determination of experimental frequencies.

Paper confirms difficulty of obtaining suitable values of frequencies for skew angles greater than 30 degrees indicated by other investigators. M. V. Barton, USA

1704. Chen, Y.-N., Linear torsional vibration with strong damping (in German), *Schweiz. Bauztg.* **74,** 46, 697–699, Nov. 1956.

Paper is an extension of earlier publication by author [AMR **8,** Rev. 588] dealing with vibration of multirotor torsional systems with significant, distributed shaft inertia and viscous friction. Present paper extends technique to cases of heavy damping,

coupled rotor systems, and vibration excitation of more than one of the rotating masses. Paper represents vibration problem as superposition of multiple torsional waves and uses complex representation and rotating vector concept.

G. A. Nothmann, USA

1705. Grobov, V. A., On the transverse vibration of a shaft rotating at variable speed (in Russian), Vopr. dinamiki i dinam. prochnosti 97–127, 1953 (Riga, Akad. Nauk Latv. SSR); Rev. no. 674, *Ref. Zh. Mekh.* 1956.

The constrained vibration of a shaft is examined, when loaded with unbalanced disks, as well as under a uniformly distributed unbalance force (closely-spaced disks), for the case of fluctuating rotational velocity. The solution is based on the following considerations: (1) The mass of the shaft is negligibly small compared with the total mass of the disks; (2) the shaft has infinitely great rigidity in torsion; (3) the gyroscopic moments of the disks due to flexing of the shaft are negligibly small; and (4) resisting forces are absent.

Differential equations are set up for the motion of the system. The equations of the first problem (for n disks) are solved by the method of operators; the solution of the second problem (distributed masses) are obtained, following the method of A. N. Krylov, as the sum of two functions, one of which satisfies the equation of vibration of the shaft without the right-hand half, as well as the boundary and initial conditions. The second component function satisfies the inhomogeneous equation and initial conditions. The case of two disks is examined in detail and the conditions for the calculation stated for arbitrary boundary conditions at the ends of the shaft; as well as the case of a uniformly distributed unbalance with freely-supported shaft ends. It is assumed in both cases that the time variation of the shaft speed is linear.

An analysis of the unsteady processes involved is appended.

Courtesy of Referativnyi Zhurnal V. S. Chuvikovskii, USSR
Translation, courtesy Ministry of Supply, England

1706. Kushul′, M. Ya., Transverse vibrations of rotating shafts in the presence of internal and external friction (in Russian), *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 10, 60–74, Oct. 1954.

1707. Perls, T. A., and Sherrard, E. S., Frequency response of second-order systems with combined coulomb and viscous damping, *J. Res. nat. Bur. Stands.* **57,** 1, 45–65, July 1956.

Response of simple vibratory system (with coulomb and viscous damping) subjected to forced harmonic motion is considered. Curves of magnification factor to frequency ratio are presented for following ratios: viscous damping 0.05 to 5.0; coulomb damping 0 to 0.9; frequency 0 to 2.0. Boundaries between 0,1, and 2 stops per half-cycle are indicated. R. N. Arnold, Scotland

1708. Grobner, W., Consideration of friction in vibration problems (in German), *Öst. Ing.-Arch.* **10,** 2/3, 171–175, 1956.

Author presents an energy method which uses variational principle. Theory is developed using expressions for kinetic and potential energy and applying Hamilton's principle and Lagrange's function. The frictional effects are treated in the variational integral as a constant multiplied by a velocity to the $(2n-1)$ power where n is a real number. While method is not limited to linear damping, it is applied to vibrating string and vibrating membrane with $n=1$ for both cases.

W. J. Worley, USA

1709. Karas, V. Z., and Ravkind, A. A., Development of an experimental prototype of a silicone torsional damper (in Russian), *Energet. byul.* no. 3, 1–12, 1955; Rev. no. 709, *Ref. Zh. Mekh.* 1956.

A torsional-vibration damper is described, containing a silicone fluid between a free ring and a casing fixed on the shaft of a reciprocating engine. The relative motion between the ring and the casing causes a part of the torsional vibrations of the engine to be absorbed in the liquid.

The fundamental analytical conditions are established, the parameters calculated, and an experimental design described of a damper for a 1200-hp diesel generator running at 428 rpm. Experimental data are given for the viscosity of oils and silicone fluids, and mixtures thereof, at different temperatures.

Courtesy of Referativnyi Zhurnal G. A. Savitskii, USSR
Translation, courtesy Ministry of Supply, England

1710. Gauss, F., Vibration behaviour of vehicles with pneumatic tires. Parts I, II(in German), *Forsch. Geb. Ing.-Wes.* **21,** 3, 87–95, 1955; 4, 123–127, 1955.

1711. Nadzhafov, E. M., Abdullaev, A. A., and Krementulo, Yu. V., Experimental investigation of natural vibrations in the internal circuits of pneumatic regulators (in Russian), *Avtomatika i Telemekhanika* **16,** 1, 27–42, 1955.

Authors describe the method and results of experimental investigations of the pneumatic regulator type 04 "Tizpribor" with internal contour consisting of two "valve-clapet" pneumatic relays coupled by inverse coupling.

The influences of the hydraulic resistance and the capacitance of the coupling on the frequency and amplitude of the natural vibrations are shown. The resistance expands the region of the vibrations toward the side of the lower damping diapasons, but increases the amplitude and decreases the frequency. Increasing the capacitance of the coupling has the same influence as increasing the hydraulic resistance.

It is shown also that a regulator of this type can be used as a regulator with continuous action or as a vibrating regulator, depending on the construction parameters and on the coupling of the input to the regulator. D. Raskovic, Yugoslavia

1712. Yates, H. G., Prediction and measurement of vibration in marine geared-shaft systems, *Instn. mech. Engrs. Proc.* **169,** 34, 611–642, 1955.

1713. Doi, S., An experimental study on chatter vibrations in grinding operations, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-6, 8 pp.

During the grinding process there frequently occurs a lateral vibration of the rotating wheel. In this experiment, that vibration was magnified under the microscope and measured on a rotating film. Many modes of vibration were ascertained experimentally, produced by irregularity of the journal of the main spindle; peripheral irregularity of the grinding wheel; a flexible main spindle; clearance in the main bearing; the driving-belt seam and the flapping vibration of the driving belt on the main spindle; a flexible workpiece; the deflection of a grinding machine, and so on. The causes and the characters of these vibrations and some preventative methods were investigated. It has been found that a plain bearing used as the main bearing of a grinder is superior to a ball bearing in so far as prevention of vibration of the wheel is concerned. From author's summary

1714. Smilovenko, D. A., and Zhilinsky, O. V., Investigation of the vibrations of a milling machine in standard and climb milling, and methods of combating them (in Russian), *Sb. Stud. Rabot. Belorus. Polytekh. Inst.* no. 2, 29–39, 1955; Rev. no. 40, Ref. Zh. Mekh. 1956.

An investigation was made of the relationship of amplitude and frequency of oscillations of the table and tool holder of a milling

machine to the speed of cutting and feed. Means of combating the vibrations using a vibro-damper, and also by placing a load on the tool holder of the machine, are examined.

Courtesy of Referativnyi Zhurnal D. F. Blokh, USSR
Translation, courtesy Ministry of Supply, England

1715. Anonymous, Vibration and pressure-cell tests flood-control intake gates, Fort Randall Dam, Missouri River, South Dakota, *Wuys. Exp. Sta. CWI Item no.* 804, 17 pp. + 12 tables + 9 plates, June 1956.

1716. Macduff, J. N., and Felgar, R. P., Vibration frequency charts, *Mach. Design* **29,** 3, 109–115, Feb. 1957.

Wave Motion in Solids, Impact

(See also Rev. 1850)

1717. Jones, R. P. N., The reflection of transverse waves in beams, *Quart. J. Mech. appl. Math.* **9,** 4, 499–507, Dec. 1956.

The results derived from the simplest equation of motion for waves of bending and from Timoshenko's approximation, which includes corrections for the effects of shear displacements and rotary inertia, are compared, with particular reference to the reflection coefficients applicable when a wave is incident upon (1) a simply supported, (2) a free, or (3) a clamped end. The propagation and reflection of a pulse due to a transverse impact are briefly discussed.

Timoshenko's approximation yields two modes; one which is progressive at all frequencies and is almost a pure wave of bending at low frequencies, one which is progressive above a critical frequency and stationary below. The characteristics of the first mode are in good agreement with those given by the exact theory; no comparison has been made between the results of Timoshenko's approximation and the exact theory for the second mode. It is unfortunate that the author has not given such a comparison so that the range of validity of the reflection coefficients presented, which are critically dependent upon the phase velocities of both modes, might be properly assessed.

M. J. P. Musgrave, England

1718. Ghosh, M., and Ray, K. D., Dynamics of the vibration of a bar excited by transverse impact of a hard load, Part I, *Indian J. theor. Phys.* **3,** 2, 77–82, June 1955.

Authors consider the problem of lateral impact on a uniform cantilever beam. The impact is produced by collision of a solid mass with the beam at its free end. The solution is made by writing the general solution of the lateral motion in terms of an operator $D = d/dt$, and by matching the boundary condition at the free end. The operational equation so obtained is then solved approximately by retaining terms only up to the second power of D. The time history of the contact pressure is found to be half sine shape. Authors also develop expressions for the duration of impact and the energy transmitted in terms of the ratio between the mass of the beam and the impact mass. Experimental observations support the analytical results on the energy transmitted during impact.

Authors apparently are not aware of the recent works in the U.S. on lateral impact of beams [AMR **1,** Rev. 1071 and AMR **4,** Rev. 2822].

T. H. H. Pian, USA

1719. Knopoff, L., The seismic pulse in materials possessing solid friction, I: Plane waves, *Bull. seism. Soc. Amer.* **46,** 3, 175–183, July 1956.

Considering the fact that viscoelastic materials with the property of Jeffreys-Ricker model are rare and most solid materials have solid friction, author studied the wave propagation (one-dimensional) in such a medium.

Two problems are treated: one is the case of simple impulse of displacement, and the other is that of stress doublet, impressed at $x = 0$ and $t = 0$. In the latter case, solutions have a symmetric and an antisymmetric part. In every case the amplitude of the crest diminishes and the impulse becomes flat and broad as it is propagated.

Author concludes, "This kind of media is a rare instance in which there can occur a frequency-dependent absorption without attendant dispersion. The group velocity is equal to the phase velocity. Since it has been established that pulse broadening does occur, an important conclusion may be drawn; it is fallacious, in this case at least, to associate a definite frequency with any particular part of the seismic wave form." Y. Sato, Japan

1720. Volterra, E., Some applications of the method of "internal constraints" to dynamic problems; Deformation and flow of solids, Colloquium Madrid, Sept. 26–30, 1955, 236–250; Berlin, Springer Verlag, 1956.

Equations of motion of a curved bar are developed in a general manner from Hamilton's principle under the constraint that sections originally normal to the axis of the bar remain plane during motion. These equations are then reduced to the case of a straight bar and examined for the one-dimensional theory of wave propagation. Propagation of longitudinal waves is compared to previous findings of Rayleigh and R. M. Davies. Propagation of flexural waves is compared to results of Mindlin, Davies, and Timoshenko.

W. T. Thomson, USA

1721. Shemyakin, E. I., and Fainschmidt, V. L., Wave propagation in an elastic semi-space influenced by a tangential surface force (in Russian), *Uchen. Zap. Leningr. un-ta,* (177), *Ser. Mat. n.* no. 28, 148–179, 1954; Rev. no. 1045, *Ref. Zh. Mekh.* 1956.

The elastic oscillations are examined, arising in a homogeneous and isotropic semi-space $z \geqslant 0$ under the action on the boundary $z = 0$ of a source of the type of a concentrated, tangential force. A Cartesian system of coordinates, x, y, z is introduced, the origin of which coincides with the point of application (of the force) and the positive direction of the x-axis, with the direction of action of the force.

The solution of the problem, presented initially in the form of triple integrals, is determined by the method of incomplete division of the integrals applying Fourier transformations along the coordinates x and y, and a unilateral Laplace transformation along the axis z (time, t). The transformation into polar coordinates for the final equations is effected by the substitutions $x = r \cos \theta$, $y = r \sin \theta$, $z = z$, and enables the double Fourier integrals to be represented by Fourier-Bessel integrals. Thus the solution for the asymmetrical problem is found to be expressed by identical integrals to those occurring in the known solutions for the symmetrical problem. The relationship between the solution constructed and the θ coordinate is merely expressed in the fact that the component u_θ of the displacement vector on the θ axis contains $\sin \theta$ as a multiplier, while the multiplier of the components u_r and u_z (correspondingly on the r and z axes) is $\cos \theta$.

The detailed solution of the constructed solutions is obtained in the same manner as in the case of axially symmetrical problems: applying the deduction theorem, the method of the steady phase, and asymptotic evaluation [*Ucb. Zap. Leningr. un-ta,* (149), *Ser. Mat. n.* 24, 1951]. In this manner, it has been possible to resolve and analyze the separate parts of the total vector field of the displacements having independent physical significance.

It has been found that the longitudinal and transverse waves, as well as the surface wave, in the components u_r and u_z of the vector of the displacement field are represented (qualitatively)

by the same characteristics as in the case of axially symmetrical problems. The three-dimensional longitudinal and transverse waves are comparable in magnitude. In the component u_θ the purely transverse wave SH predominates, since the intensities of the longitudinal and superficial waves are weaker by one order of magnitude than in the components u_r and u_z.

A solution of the problem investigated by these authors has already been presented, using other methods, e.g., by E. A. Naryshkina [*Tr. Seismol. in-ta Akad. Nauk. USSR* no. 45, 1934]. These previous researches did not, however, give any detailed analysis of the solution. K. I. Ogurtsov, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1722. Cristescu, N., Some remarks on the propagation of plastic waves in plates (axisymmetric case) (in Russian), *Prikl. Mat. Mekh.* **19**, 4, 433–442, July/Aug. 1955.

Author presents theoretical investigation of an infinite plate with circular opening under stresses beyond elastic limit when the material becomes plastic. At this stage plastic waves are propagated with certain amplitude and with stresses to be determined by differential equations. Analogous problems pertaining to plane deformations of infinite rods and cylinders were solved by H. A. Rahmatulin and V. V. Sokolovsky. Reference is made to W. Freiberger's method of solving problems in dynamic plasticity in a flat sheet with circular hole, and to H. Hugoniot's early investigations (1887). J. J. Polivka, USA

1723. Huth, J. H., Thompson, J. S., and Van Valkenburg, M. E., Some new data on high-speed impact phenomena, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-15, 4 pp.

Paper presents a summary of some recent experimental work aimed at evaluating the role of various physical parameters in high-speed impact phenomena. It is shown that penetration into thick targets by projectiles of the same material, for certain common metals, can be expressed approximately through a single relationship of the form $(p/d) = 2.5(V/c)^{1.4}$ in a range of about $0.1 \leq (V/c) \leq 1.0$. Here p represents penetration (crater depth) measured from the initial target surface, d a characteristic dimension of the projectile, and V the impact velocity. c is the "sonic" velocity in the projectile and target material as expressed by the formula $c = \sqrt{E/\rho}$, where E is Young's modulus and ρ the density. Experimental results are given for steel, aluminum, brass, lead, magnesium, and a magnesium-lithium alloy.

From authors' summary

1724. Grzedzielski, A., Eccentric landing with heavy masses at the wing tips, *J. aero. Sci.* **23**, 7, 653–659, 678, July 1956.

Presumably, the landing gears contact the ground one after the other, the second contact taking place before the shock absorbing process of the first gear is completed. In order to solve the equations of motion, a nondimensional function for the assumed time history of the landing gear reactions is introduced. It is found that, in eccentric landing, the effective mass acting on one shock absorbing unit may be larger than one half of the total mass of the aircraft. The magnitude of this mass depends on the ratio, radius of gyration of the aircraft in roll to the undercarriage tread, on the initial roll angle, and on the roll velocity at the moment of the first contact. Furthermore, it is possible that the aircraft receives two shocks of the same magnitude timed so that an asymmetric wing vibration can be generated having larger effects on wing stresses than the symmetric vibration due to the symmetric landing

J. Rotta, Germany

1725. Feder, J. C., Gibbons, R. A., Gilbert, J. T., and Offenbacher, E. L., The study of the propagation of stress waves by photoelasticity, *Proc. Soc. exp. Stress Anal.* **14**, 1, 109–122, 1956.

Paper describes the techniques used in the study. In one group of experiments electric primers were used to propel steel rods against small rectangular specimens of Columbia Resin CR-39. In a second group of experiments detonations were applied directly to the specimens by the explosion of blasting caps.

In a discussion of the paper by Durelli, Riley, and Dally excellent photographs are shown of the wave propagation in a gelatin strut subjected to impact and in an epoxy resin plate.

D. Young, USA

1726. Keller, J. B., Lewis, R. M., and Seckler, B. D., Asymptotic solution of some diffraction problems, *Comm. pure appl. Math.* **9**, 2, 207–265, May 1956.

A method to determine directly the asymptotic expansion of a periodic solution with respect to frequency, as the frequency tends to infinity, of the linear wave problems is explained and used to solve a large variety of diffraction problems. It is shown to be of particular merit when the exact solution has not been found. Geometry of systems considered imposes limitations (e.g., diffracted ray problems as yet cannot be solved by this method).

Examples of the many problems analyzed include: Cylindrical waves, spherical waves, general plane waves, arbitrary waves, two-dimensional waves, axially-symmetric waves, and the case of reflection from a surface on which an impedance boundary condition is to be satisfied. The expansions are useful for high frequencies (i.e., short wave lengths).

Mathematically the problem in each case is to find the asymptotic expansion of the solution of a boundary-value problem for an elliptic equation. This excellent paper forms a major contribution to wave diffraction problems. Z. W. Dybczak, Canada

Elasticity Theory

(See also Revs. 1742, 1754, 1790, 1794, 1795, 1920)

1727. Blanc, C., Stochastic study of errors of approximate solutions of two-dimensional elasticity problems (in French), *Bull. tech. Suisse Rom.* **83**, 1, 1–5, Jan. 1957.

Author proposes a method of estimating theoretical errors $\xi = \sigma_x^0 - \sigma_x$, etc., involved in the approximate solution of partial differential equations:

$$\partial\sigma_x/\partial x - \partial\tau/\partial y = 0,\ \partial\sigma_y/\partial y - \partial\tau/\partial x = 0,\ \Delta(\sigma_x + \sigma_y) = F(x,y).$$

The errors are caused by replacing $\partial f/\partial_x$, etc., by $\delta f/\delta x = f(x + \frac{1}{2}, y) - f(x - \frac{1}{2}, y)$, etc. They satisfy the difference equations: $\delta\xi/\delta x - \delta\eta/\delta y = t$, etc., where $t = (\partial/\partial x - \delta/\delta x)\sigma_x - (\partial/\partial y - \delta/\delta y)\tau$, etc. Now, assuming that σ_x, etc., are stochastic variables with mean value zero and covariance $E\sigma_x(x_1,y_1)\sigma_x(x_2,y_2) = \int\int As(\alpha)s(\beta)e^{i[(x_2-x_1)\alpha+(y_2-y_1)\beta]}d\alpha d\beta$, etc., one can compute the covariance $Et(x_1,y_1)t(x_2,y_2)$ and hence $E\xi^2$, etc. Author adds an example, for which $A = 0.334$, $s(\alpha) = \frac{1}{1.2}$ if $|\alpha| \leq 0.6$, $= 0$ if $|\alpha| > 0.6$, the result at a certain point being $(E\zeta^2)^{\frac{1}{2}} = 0.0174$.

This is another example of the same idea as in author's previous papers [*Comment. math. helv.* **26**, p. 225, 1952; *Arch. Math.* **5**, p. 301, 1954; *ZAMP* **7**, p. 146, 1956; *ZAMM* **35**, p. 121, 1955 (AMR **9**, Rev. 973)]. S. Moriguti, Japan

1728. Muckle, W., Stresses in the neighbourhood of discontinuties, *N. E. Cst. Instn. Engrs. Ship. Trans.* **73**, 1, 29–36, Nov. 1956.

Author calls attention to the analogy that exists between the normal displacement of a flat plate in flexure and the Airy stress function used in solving plane stress problems in flat plates. On the basis of this analogy he suggests solving intractable ex-

tensional problems of flat plates by using experimental methods to solve the analogous bending problem, taking as an example the problem of a flat plate in plain tension with a rectangular hole. Author is apparently unaware that this analogy was treated exhaustively by Southwell in 1950 [AMR **4,** Rev. 1077], as the simpler of two distinct analogies connecting tension and flexure. The problem of plates with holes is also specifically discussed by Southwell.

Reviewer believes author's suggested experimental approach impracticable since it involves awkward (from a laboratory viewpoint) boundary displacement conditions and also the need for measuring curvature. D. Williams, England

1729. Mossakovskii, V. I., First fundamental problem in the theory of elasticity for space with a plane circular aperture (in Russian), *Prikl. Mat. Mekh.* **19,** 4, 443-452, July/Aug. 1955.

The title problem is reduced to four separate problems, two of which have been solved previously [M. Ya. Leonov, title source **4,** no. 5/6, 1940 and **17,** no. 1, 1953]. Author solves presently the two remaining cases and shows that a previous treatment by S. G. Mikhlin [title source **10,** no. 2, 1946] is erroneous.

G. Herrmann, USA

1730. Truesdell, C., The unsolved principal problem of the finite theory of elasticity (in German), *ZAMM* **36,** 3/4, 97-103, Mar./Apr. 1956.

Excellent review of a fundamental problem and of the attempts made to solve it is presented in the field of the finite theory of elasticity, i.e., the nonlinear mechanics of perfectly elastic continua undergoing large deformations. The problem is to specify the class of functions which can serve as strain-energy functions for the finite deformation of perfectly elastic materials. (In the usual linear theory this function is a positive definite quadratic form.) Clear exposition of the background, of the formulation, and of the present-day status of the solution is given. Hadamard's (1903) and Ericksen's (1953,1954) contributions are reviewed and compared with author's fundamental work on the subject [see, e.g., *J. rational Mech. Analysis* **1,** 125-300, 1952 and AMR **6,** Rev. 2467]. One of author's conclusions is that present theories are incomplete, including his own conditions which are conjectured to be necessary but not sufficient.

Article brings reader up to date regarding one of the important and fundamental questions of the finite theory of elasticity.

V. G. Szebehely, USA

1731. Teleman, S., The method of orthogonal projection in the theory of elasticity, *Acad. Repub. pop. Rom. Rev., Math. pures appl.* **1,** 1, 49-66, 1956.

1732. Heaps, H. S., The distribution of stress in an infinite inhomogeneous elastic medium, Proc. second Midwestern Conf. solid Mech., Purdue Univ., Sept. 1955. 14-24.

The effect of spatial variation in the elastic parameters λ,μ taken to be $\lambda_0 + l(x)$ and $\mu_0 + m(x)$, respectively, where l,m are so small that the second-order terms are neglected, has been considered. The displacements u_i being represented by $v_i + w_i$, the differential equation of equilibrium in u_i has been split into one in v_i with λ_0,μ_0 as elastic constants and another similar equation in w_i with the body force term in the first replaced by a function involving v_i and variation of l,m. Three-dimensional Fourier transform has been applied to solve the differential equation and it has been shown that stress at any point is the stress at the point in material of constant elastic parameters together with two correction terms, the first showing the effect of variation of elastic parameters at that point and the second describing the accumulated effect of variations elsewhere. Cases of inhomogenous material under gravitational force or force at a single point have been illustrated. D. N. Mitra, India

1733. Terrington, J. S., Behaviour of built-up girders under torsion. Method of calculating stresses and distortion, *Engineering* **182,** 4731, 587-591, Nov. 1956.

Article summarizes results previously derived by the author [AMR **7,** Rev. 1768] and describes states of stress existing in a composite girder of asymmetrical section under crane-wheel loading.

Tests carried out in the Laboratory of the British Iron and Steel Research Association on full-scale and reduced-scale models seem to agree with these theoretical results. E. Volterra, USA

1734. Funaioli, E., On the torsion of lenticular prisms (in Italian), *Aerotecnica* **36,** 4, 265-269, Aug. 1956.

Prisms whose form is similar to modern airplane wing sections are studied. In order to establish the torsional behavior the form of the stress function along the median and the axis of symmetry of the lenticular section is studied. This problem is solved by means of solutions to the Diriclet problem for circular sections, using conformal mapping. In such manner it is possible to determine the maximum value of the tangential stress and to estimate the influence exercised by the curvature of the median on the tangential stress at points on the boundary situated on the axis of symmetry of the cross section.

The calculations are simplified by the observation that, in order to determine the torsional stiffness, cross sections with straight medians may replace the actual curved ones. As regards the tangential stress, the influence of the curvature is evaluated.

The analysis is simplified by replacing the functions obtained from the conformal transformation by simpler ones which are more easily evaluated. Some numerical examples are given to compare the approximate solutions with exact ones.

B. Langefors, Sweden

1735. Clauss, A., Influence of gas adsorption on the torsional elasticity of a metallic wire (in French), *C. R. Acad. Sci. Paris* **242,** 12, 1578-1580, Mar. 1956.

1736. Nakazawa, H., On the torsion of the shaft with key ways, *Mem. Fac. Technol. Tokyo Metrop. Univ.* no. 6, 1-6, 1956.

Author investigates the effect of stress concentrations due to key ways on circular-cylindrical shafts under torsion. Circular key ways are studied analytically and rectangular ones by the electrolytic tank method. The results are compared with previous work by Okubo, Taylor and Moore. W. Freiberger, USA

1737. Yamada, K., On the characteristic points of bending and torsion, *Proc. 1st Japan Nat. Congr. appl. Mech.* 1951; Nat. Committee for theor. appl. Mech., May 1952, 119-122.

1738. Coffin, L. F., Jr., An investigation of thermal stress fatigue as related to high-temperature piping flexibility, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-178, 16 pp. + 14 figs.

Paper is a summary report of a cooperative research investigation extending earlier work on the thermal stress-fatigue resistance of AISI Type 347 stainless steel. The investigation was to provide additional qualitative experimental support of the concept of fatigue design based on an allowable stress range which is embodied in the ASA-B31.1 Code Rules for Piping Flexibility Design. Two specific objectives were established, together with the findings of this research. The objectives follow:

(1) Investigation of the effect of cycling which produces tensile rather than compressive stress under the hot condition. It was found that there was no significant difference.

(2) Investigation of the effect of reducing the net mechanical strain range for a given temperature range to a point approaching the design strains for a piping system. While the temperature range was held constant, the trend of reducing the net mechanical strain range was to increase the number of cycles to failure similar to that obtained when the net mechanical strain range was reduced by lowering the temperature range under full constraint. In addition, for the same mechanical strain range, widening the temperature range decreased the number of cycles to failure.

From author's summary

1739. Jung, H., Calculation of heat exchangers (in German), *Öst. Ing.-Arch.* **10**, 4, 382–392, 1956.

Expressions were developed for the thermal stress (tangential, radial, and axial) in a thick wall tube. The tangential and radial stress were of the same order of magnitude but the axial stress was a sensitive function of the asymmetrical rotational temperature field.

The temperature distribution in the tube wall was developed for the case of laminar flow perpendicular to the axis of the tube. Since most heat exchangers are operated in the turbulent regime it would be necessary to measure the temperature distribution in the tube wall and then proceed with the stress analysis.

W. L. Sibbitt, USA

1740. Toupin, R. A., The elastic dielectric, *J. rational Mech. Analysis* **5**, 6, 849–915, Nov. 1956.

Experimental Stress Analysis

(See also Rev. 1725)

1741. Shelson, W., A photoelastic method employing scattered light for the solution of plane stress problems, *Brit. J. appl. Phys.* 7, 12, 436–439, Dec. 1956.

A method first proposed by Drucker and Mindlin without experimental demonstration is described. Three retardation fringe patterns are employed—a standard isochromatic pattern and two scattered-light patterns for perpendicular directions in the plane of the model. The two "Scalif" patterns give the sum of the principal stresses. The feasibility of the method is demonstrated with an elastic disk of Fosterite subjected to concentrated loads along a diameter.

D. C. Drucker, USA

1742. Jessop, H. T., Snell, C., and Holister, G. S., Photoelastic investigation on plates with single interference-fit pins with load applied to plate only, *Aero. Quart.* **7**, 4, 297–314, Nov. 1956.

The effect of zero, low, and high loads applied to 1-in. wide plates when push fit, low, and high interference-fit pins were inserted in holes 1/8 in. to 1/2 in. in diameter was determined. For the no-load case the maximum experimental shear stresses agreed with the theoretical solution for an infinite plate. As tension was applied, it was possible to lift the plate from the pin.

The shear stress concentration factors on a section perpendicular to the load increase with the load and decrease with hole diameter for all degrees of fit. On a section parallel to the load, the shear stress concentration factors change very little as load is applied, even after lift occurs. The tensile stresses show similar trends. Young's moduli of the pins had little effect, even though the moduli were 30 times that of the plate.

N. C. Costakos, USA

1743. Nasonov, L. N., On the stress condition around pilot holes (in Russian), *Nauch. tr. po vopr. gorn. dela, Moskov. gorn. in-ta* no. 13–14, 95–108, 1954; Rev. no. 1066, *Ref. Zh. Mekh.* 1956.

Results are presented of investigations by a method of optical polarization of the stress condition arising by the action of structural weight in flat (two-dimensional) models of an optically active material on a glycerine-gelatine foundation next to freely supported and constrained holes of different shapes: trapezoidal, vaulted, arched, with contour curves represented by circles, parabolas, ellipses, etc.

Each such model represents a sheet of optically active material with a free or constrained (rigidly or elastically) hole of any of the aforementioned particular forms. Conclusions are presented on the influence of shape of the hole or cutout, or rigidity of the constraint, on the picture of the stress condition, the value of the concentration coefficient, magnitude of the influencing zone, etc.

Courtesy of Referativnyi Zhurnal G. N. Savin, USSR
Translation, courtesy Ministry of Supply, England

1744. Norris, C. B., James, W. L., and Drow, J. T., A strain gage for the measurement of strains in adhesive bonds, *ASTM Bull.* no. 218, 40–49, Dec. 1956.

A method is described for measurement of tensile strain in a thin adhesive bond between metallic adherends, by measuring the change in the electrical capacitance of the specimen. Accurate evaluations of strain can be made if the effect of changes in glue-line thickness on the dielectric constant can be determined. For some adhesives, this effect may be calculated using the Lorenz-Lorentz equation relating dielectric constant to density, when density is assumed to vary inversely with the thickness of the glue bond.

From authors' summary

1745. Kelsey, R. A., Measuring non-uniform residual stresses by the hole drilling method, *Proc. Soc. exp. Stress Anal.* **14**, 1, 181–194, 1956.

Method of determining residual stresses by drilled-hole (Mathar-Soete) method is presented for stress fields varying in thickness direction. Electric strain gages are used near hole for measurement of stress relaxation. Calibration is carried out by applying external tensile load or constant bending moment to strip. Mathar method, of which present method is a development, was criticized [Mesmer, J., *Arch. Eisenhüttenw.* **10**, no. 2, 1936] because drilling of hole causes stress concentrations producing plastic deformations vitiating results of measurements. In present paper this effect is evaded by restricting loading of specimens to 30% of flow stress. If, however, method were applied to measurement of residual stress, results obtained in regions where residual stress exceeds one third of flow stress—and these are the most important regions—would be no longer reliable.

R. Weck, England

1746. Danforth, C. E., and Anderson, B. R., Vibratory stress measurements in multistage compressor blading, *Proc. Soc. exp. Stress Anal.* **14**, 1, 21–34, 1956.

Author describes 60-channel system for monitoring stresses, dynamic pressures, and hot-wire anemometers; system is used in development of axial flow compressors. Selection of strain gages and strain-gage locations to indicate maximum blade stresses in vibration modes of interest are discussed. An interesting feature is the monitoring of the stresses, keeping in mind the *S-N* curve for the blade material, so that the test can be terminated before failure occurs. Article concludes with a section on interpretation of strain-gage wave forms for various types of phenomena—such as resonance, heavy loading, surge, flutter, critical Mach number, and spurious signals.

A. A. Regier, USA

1747. Sandorff, P. E., Design of structural models, with application to stiffened panels under combined shear and compression, *J. aero. Sci.* **23**, 7, 623–632, July 1956.

Practical methods for the design of structural test specimens are presented, based on the principle of exploring a specific mode of

failure rather than the customary indefinite investigation of structural behavior in general. This approach makes possible considerable simplification in specimen construction, through application of similitude relations, without introducing unknown restrictions on the validity of the results. Illustration is provided by application to the problem of interaction relations for stiffened-skin panels under combined compression and shear, with good correlation between predicted and experimental results.

From author's summary by E. E. Sechler, USA

Rods, Beams, Cables, Machine Elements

(See also Revs. 1700, 1717, 1720, 1733, 1736, 1776, 1781, 1795)

1748. Czitary, E., Behavior of a cable on a pulley with elastically deformable lining (in German), *Öst. Ing.-Arch.* **10,** 4, 349–359, 1956.

Problem deals with a cable stretched, say horizontally, between two fixed points and loaded vertically at the middle through a pulley with an elastically deformable lining around its circumference, a finite portion of the lining being thus compressed and brought in contact with cable. Maximum slope of cable is assumed to be small. In addition to the main problem in which flexural rigidity EJ of cable is considered, a special case in which EJ is neglected is also discussed. Then, in two other special cases of considering and neglecting EJ of cable, respectively, a rigid pulley without lining is considered. Obtained for all cases are expressions for determining length of contact between cable and pulley, elevation of pulley, minimum radius of curvature ρ_0 of cable, and maximum pressure σ_0 between cable and pulley, the last two quantities occurring at center of cable. Numerical example shows much larger ρ_0 and lower σ_0 for the cases of pulley with elastic lining than for those of rigid pulley without lining; use of lining such as that made of rubber is therefore justified.

Reviewer likes to point out that author's differential equations governing deflections of compressed and free portions of cable in main problem are similar to those for beams under simultaneous axial and transverse loading, with and without an elastic foundation, respectively, because EJ of cable is considered; and that, when pulley has elastic lining, the numerical results show little difference between considering and neglecting EJ of cable, indicating that EJ may well be neglected to have much simpler calculation. In the first unnumbered equation in paper, for computing the moment in cable, term Px_0 should be $P(x_0 + x)$, but the error fortunately does not affect the rest of the calculations.

Y.-Y. Yu, USA

1749. Ter-Martichiyan, A. N., On the theory of the rigidity of thin rods (in Russian), *Trudi Tulsk. mekh. in-ta* no. 7, 182–185, 1955; Rev. no. 1070, *Ref. Zh. Mekh.* 1956.

Six equations for the equilibrium of a thin rod, presented by Kirchhoff and Klebsch, are reduced to four differential equations referring to the displacements and angle of rotation of the rod cross section. It is demonstrated that it is possible, for the particular case, to derive from these four equations, the equation for a thin-walled rod (tube). P. A. Lukash, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1750. Babakova, O. I., On the torsion of bars of Z cross section (in Ukrainian), *Dopovidi Akad. Nauk Ukrain. RSR* no. 5, 319–323, 1954; Rev. no. 1073, *Ref. Zh. Mekh.* 1956.

The problem is examined of the torsion of a bar of polygonal cross section S, the boundaries of which are formed by rectilinear segments, parallel to the coordinates axes. In order to simplify the calculation of $F^{\circ}(z(\zeta)) = s + it$ by the familiar Trefftz formula ($F(z)$ = torsional function, $z(\zeta)$ = a function projecting the semiplane $\mathrm{Im}\zeta > 0$ on S), it is suggested to determine the function $s_0 + it_0$, $\mathrm{Im}\ t_0 = \pm 1$ on the segments of the axis $\mathrm{Im}\zeta = 0$ corresponding to the bounding segments of the area S, by the Schwartz formula, and then to find the rational difference $s + it - (s_0 + it_0)$ from the properties of the Trefftz formula. The expression found in this manner for $s + it$ is applied to the solution of the problem of the torsion of a bar of Z cross section, with infinitely long side bands of equal width. For the particular case, the calculation is conducted, after determining the coefficients of the expression $s + it$, as far as the construction of curves of stress for the outline of the cross section. P. P. Kufarev, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1751. Polyevko, V. P., The longitudinal and transverse bending of flexible prismatic rods (in Russian), *Trudi Vses. n.-i. in-ta zh.-d. str-va i proyektirovania* no. 16, 124–144, 1955; Rev. no. 1079, *Ref. Zh. Mekh.* 1956.

The case is examined of elastically constrained rods under varying transverse loading, as well as the case of equal fixed-end moments and equal coefficients of constraint, for the triangular diagram of the initial bending moments and equal rigidities of the end constraints, and the diagram of moments for a twisted trapezoid with equal end constraints.

Courtesy of Referativnyi Zhurnal A. F. Rozhnyatovskii, USSR
Translation, courtesy Ministry of Supply, England

1752. Zyulin, P. K., On the rigidity calculation for multiple-span, cantilever beams by the method of forces (in Russian), *Sbornik nauch. tr. Magnitogor. gorno-metallurg. in-ta.* no. 7, 388–403, 1954; Rev. no. 1080, *Ref. Zh. Mekh.* 1956.

The cases are examined for a multiply-supported beam with a cantilever capable of rotation, as well as a multiply-supported beam with a cantilever the end of which is capable of motion in a direction perpendicular to the axis of the beam, but which cannot rotate. Tables are given for the values of the functions:

$$F(u) = \frac{1}{2u}\frac{1}{\tan 2u}, \quad V(u) = \frac{\tan 2u}{2u}.$$

Courtesy of Referativnyi Zhurnal A. F. Rozhyatorskii, USSR
Translation, courtesy Ministry of Supply, England

1753. Tarasenko, I. I., A comparison of the limiting stresses and deformations in tension and simultaneous torsion and tension (in Russian), *Trudi Leningr. politekh. in-ta* no. 178, 232–237, 1955; Rev. no. 1192, *Ref. Zh. Mekh.* 1956.

An investigation of the ultimate strength of structural steel in axial tension and combined torsion and tension. The modulus of plasticity is assumed as a function characterizing the resistance to viscous fracture, in addition to the value of the tangential stress. Evaluating experimental data obtained for thin-walled tubes under simple loading, author has found a better coincidence of the values of the plasticity modulus at fracture than in the case of the maximum, or octahedral, tangential stresses.

Courtesy of Referativnyi Zhurnal V. A. Bykov, USSR
Translation, courtesy Ministry of Supply, England

1754. Williams, T. S., Stresses in large ring bearings, *Prod. Engng.* **28,** 2, 160–163, Feb. 1957.

Inner races of large ring bearings experience concentrated loads from mounted structures. For analysis of forces, inner race is treated as an infinite beam resting on an elastic foundation. Formulas for stress problems, graphs, and sample calculations are given for typical problem. From author's summary

1755. Gibson, J. E., and Jenkins, W. M., The stress distribution in a simply-supported beam with a circular hole, *Struct. Engr.* **34,** 12, 443–449, Dec. 1956.

The problem is investigated both theoretically and experimentally for the case of bending with shear. The line of action of the point load coincides with the vertical diameter of the hole. The theoretical values of the stress in the neighborhood of the circular hole give reasonable agreement with experimental values determined photoelastically and from steel beam tests. The maximal value of the tangential stress on the boundary of the hole is twice the value that would occur at the same distance from the neutral axis in a beam with a continuous web. The investigation is preliminary to a more extensive program of work with beams having square and hexagonal holes.

L. Foppl, Germany

1756. Zasedatelev, S. M., The loss of rigidity in tension springs (in Russian), Rasschety na prochnost' elementov mashinostroit. konstruktsii. Moscow, 120–125, 1955; Rev. no. 1071, *Ref. Zh. Mekh.* 1956.

A spring coiled with initial tension (pressure between the coils) may lose its rigidity in tension. This loss of rigidity is expressed in the canting of the coils (turns). Solving the problem by energetic analysis, author obtains an expression for the critical value of the tangential stresses (E = modulus of elasticity, c spring constant)

$$\tau_{Kr} = \frac{E}{\pi c^2}$$

The phenomenon of loss of rigidity arises in springs with a constant exceeding

$$c = (E/\pi\tau_T)^{1/2}$$

(τ_T – elastic limit of the material in shear).

Courtesy of Referativnyi Zhurnal L. E. Andreeva, USSR
Translation, courtesy Ministry of Supply, England

1757. Ignatenko, V. V., Stresses in coil windings (in Russian), Rasschety na prochnost elementov mashinostroit. konstruktsiy, Moscow, 99–108, 1955; Rev. no. 1136, *Ref. Zh. Mekh.* 1956.

Formulae are derived for determining the stresses in a filament (wire) coiled on a cylindrical core, and the pressure exerted by one turn on another. The solution is given in the first instance for an entirely rigid core, and secondly, for a deformable core. The solutions are approximate, hence there is some divergence between the results obtained and the initial assumptions, as stated by the author himself. I. I. Trapezin, USSR
Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Plates, Disks, Shells, Membranes

(See also Revs. 1722, 1742, 1747, 1748)

1758. Hodge, P. G., Jr., Piecewise linear isotropic plasticity applied to a circular cylindrical shell with symmetrical radial loading, *J. Franklin Inst.* **263,** 1, 13–34, Jan. 1957.

A theory of plasticity is developed with specific reference to a circular cylindrical shell subjected to axially symmetric radial loading. The yield condition is expressed in terms of stress resultants and is represented by a square in stress space. The plastic potential flow law is extended to include the corners of the yield condition, under the assumption that the strain-hardening is isotropic and linear. Next, the flow law at all points is piecewise integrated and expressed as a direct relation between stress and strain but containing unknown functions. Under certain restrictions on the loading, the two classical minimum principles of minimum potential and complementary energy are shown to be valid. Finally, these minimum principles are applied to an example and compared with the exact solution.

From author's summary by A. D. Topping, USA

1759. Simons, R. M., A power series for the nonlinear equations for axi-symmetrical bending of shallow spherical shells, *J. Math. Phys.* **35,** 2, 164–176, July 1956.

A shallow segment of a thin spherical shell is subjected to uniform normal pressure. Two types of edge restraints are considered: simply supported and clamped. E. Reissner's two well-known nonlinear equations, non-dimensionalized, contain two parameters: a geometrical one, zero for a flat plate, and a load parameter, the factor of the nonlinear terms. The solution in the form of two power series in powers of the angle between apex and variable point contains two leading coefficients, and all succeeding coefficients of the series can be computed from nonlinear recursion formulas. The principal contribution of the paper is a systematic interpolation procedure for obtaining the appropriate choices of the leading coefficients in order to satisfy the prescribed boundary conditions. H. Schaefer, Germany

1760. Galletly, G. D., and Bart, R., Effects of boundary conditions and initial out-of-roundness on the strength of thin-walled cylinders subject to external hydrostatic pressure, *J. appl. Mech.* **23,** 3, 351–358, Sept. 1956.

Using classical small-deflection theory, equations were developed for initially out-of-round cylinders with clamped ends. These equations, and those derived by Bodner and Berks for simply supported ends, were applied to some actual test results. Authors show (1) that, if the initial out-of-roundness is determined according to Holt, experimental and theoretical results agree quite well; (2) that while the difference in collapse pressures for clamped-end and simply supported perfect cylinders may be quite considerable, this does not appear to be the case when initial out-of-roundness of practical magnitude is considered.

From authors' summary by J. W. Cohen, Holland

1761. Boyce, W. E., The bending of a work-hardening circular plate by a uniform transverse load, *Quart. appl. Math.* **14,** 3, 277–288, Oct. 1956.

Plate behavior is analyzed on assumption of rigid work-hardening material.

To overcome shortcomings of total stress-strain laws, a compromise suggested by Prager is adopted, namely, use of a segmentwise linear yield condition with associated flow rules. For completeness, a brief summary of the Prager method, applicable to plane stress, is included. It is indicated that resulting modified behavior corresponds to use of total stress-strain laws in the small together with incremental laws in the large.

Details of present problem analysis follow. Initiation of plastic flow is predicted by theory of rigid perfectly plastic solids. For further increase in load, and so work-hardening, four separate zones of plate require consideration. Analyses leads to expressions for moment, deflection, and radii of zone boundaries.

With p_0 as load intensity initiating yield, moments and deflections are presented, tabular and graphically, for loads of $p/p_0 = 1.0, 1.25, 1.5$. Comparison is made with earlier results of Prager; disagreement seems considerable.

F. S. Shaw, Australia

1762. Bassali, W. A., Bending of an elastically restrained circular plate under a linearly varying load over an eccentric

circle, *Proc. Camb. phil. Soc.* **52,** 4, 734-741, Oct. 1956.

The complex potentials and deflection at any point of a thin circular plate with a normal linearly varying load over an eccentric circle are determined under a general boundary condition including the usual clamped and hinged boundaries.

From author's summary by T. H. Lin, USA

1763. Clarkson, J., A new approach to the design of plates to withstand lateral pressure, *Trans. Instn. nav. Arch. Lond.* **98,** 4, 443-463, Oct. 1956.

This moderately long paper constitutes a realistic study of the nature of the problem of the lateral loading of flat plates as encountered in technology and especially in naval architecture. The standard equation of Lagrange for the case of small elastic deflections is discussed and shown to be wanting in terms of some of the requirements of engineering construction. The extension to the case of larger elastic deformation is briefly reviewed in the light of the plate equation of von Kármán and some of its noteworthy solutions by S. Levy. The major portion of the paper is then devoted to the case of plastic deformation and its relation to the notions of plastic hinges and limit design. Plasticity considerations are closely related to the work of W. Prager in this country and T. F. Baker in England. Interesting experimental data are presented in the form of curves. As an example of progressive development of plastic action, a clamped square plate is represented in a series of pictures corresponding to the increase of the lateral load.

Reviewer believes that anyone interested in the design of flat plates will probably wish to read this paper.

W. H. Hoppmann, II, USA

1764. Muggenburg, H., Influence surfaces for a half circular plate with a fixed circular arc and a free diametral edge (in German), *Ing. Arch.* **24,** 5, 308-316, 1956.

Approximate influence surfaces for deflection, moment, and shear are obtained with a concentrated force at center of diametral edge. Plate is assumed isotropic and classical theory is used. Boundary condition on arc is satisfied only approximately. Numerical results are presented in graphical form.

J. L. Bogdanoff, USA

1765. Huggins, M. W., and Lin, W. L., Moments in flat slabs, *Proc. Amer. Soc. civ. Engrs.* **82,** ST 4 (J. Struct. Div.), Pap. 1020, 29 pp., July 1956.

Paper summarizes the results of a study of moments in a cast aluminum model of a flat slab floor. All panels were square, and the columns and capitals were round. There were no drop panels. The model was two bays by three bays and was tested under air pressure with a pattern-type loading.

Moments obtained from SR-4 strain gage readings are compared with those obtained by continuous frame analysis following the American Concrete Institute Code (ACI-318-51).

From authors' summary

1766. Yushchenko, O. A., The bending of a thin plate (in Ukrainian), *Dopovidi Akad. Nauk. Ukrain. RSR* no. 6, 431-434, 1954; Rev. no. 1021, *Ref. Zh. Mekh.* 1956.

The behavior of a freely supported plate under a uniform lateral pressure is investigated by the grid method for the case of large deflections.

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1767. Haringx, J. A., Non-linearity of corrugated diaphragms, *Appl. sci. Res.* **(A) 6,** 1, 45-52, 1956.

Proceeding from the method of calculation for determining the rigidity of corrugated diaphragms given earlier, one is able to indicate what degree of nonlinearity of the relations between load and deflection is to be expected for large deformations. By means of an example it is shown that the introduction of the corrugations into the flat plate, though unavoidably increasing the initial rigidity, involves an important gain in maximum deflection for the same degree of nonlinearity.

From author's summary

1768. Biot, M. A., Variational and Lagrangian methods in viscoelasticity; Deformation and flow of solids, Colloquium Madrid, Sept. 26-30, 1955, 251-263. Berlin, Springer Verlag, 1956.

Author develops, using Onsager's reciprocity relations, a very general formulation of relations between stress and strain in linear viscoelasticity in operational form. It is shown that a variational formulation of deformation and stress field problems leads to a generalization of Lagrange's equations. A formal correspondence between problems in viscoelasticity and elasticity theory is possible. A new approach to the dynamics of plates or shells for isotropic or anisotropic media is developed. This can also be used in the elastic theory of plates and shells when the effect of increasing thickness is taken into account. As an example, the theory is applied to determine the deflection of an isotropic viscoelastic plate. Two nonlinear integro-differential equations, when solved, yield the deflection.

E. J. Scott, USA

Buckling Problems

(See also Revs. 1759, 1777)

1769. Van Schravendijk, J. F., Buckling of centrally compressed reinforced-concrete columns (in Dutch), *Ingenieur* **68,** 43, 85-96, Oct. 1956.

A theory for the buckling of centrally loaded reinforced-concrete columns is developed based upon the Engesser-Shanley treatment for plastic buckling and on a simplified form of Renger's stress-strain formulas for concrete. The density, elasticity, and elastic characteristics of the concrete are fully taken into account. The theory is shown to be in good agreement with test results obtained recently by Graf and Gehler in Germany. It is proved that designs based upon existing German or Dutch standards have much lower safety factors than usually assumed. W. A. Nash, USA

1770. Zuk, W., Lateral bracing forces on beams and columns, *Proc. Amer. Soc. civ. Engrs.* **82,** EM 3 (*J. Engng. Mech. Div.*), Pap. 1032, 16 pp., July 1956.

Author has "derived quantitatively the amounts of bracing force required for eight representative cases of beams and columns... In all cases the behavior is assumed elastic."

Numerous errors appear on page 2 in solution of Case I. Also in Eq. (1.1) three-term bracket in numerator reduces to constant 2, and last three terms of denominator reduce to $-L/B_1 p$. Such careless presentation leaves reviewer doubtful of reliability of results.

F. J. McCormick, USA

1771. Guest, J., A lower-bound solution to the buckling stress of uniformly clamped parallelogram plates, *Austral. J. appl. Sci.* **7,** 4, 336-345, Dec. 1956.

Lower bound estimates for the linear elastic buckling of thin clamped parallelogram plates under uniform compression on two sides is investigated analytically, using Rayleigh-Ritz techniques with Lagrangian multipliers as previously developed at the NACA. Numerical results show excellent correlation with published data on square and rhombic plates with an included angle of $\pi/3$. How-

ever, author's comparison with Wittrick's result for rhombic plates with $\pi/4$ included angle is obviously in disagreement, since Wittrick's upper bound is shown smaller than author's lower bound. Author's comment that decreasing the sweep angle widens the gap between the upper and lower bounds due to poor convergence would not account for the aforementioned discrepancy, since one would expect the upper bound to increase, the lower to decrease.

N. Grossman, USA

1772. Schmitt, A. F., Dynamic buckling tests of aluminum shells, *Aero. Engng. Rev.* **15,** 9, 54-58, Sept. 1956.

A test program is described: Thin-walled shells were buckled by the axial impact of high-velocity masses. The mode of buckling failure in the dynamic case was significantly different from that in static tests. An empirical relationship for energy absorbed versus impact velocity was found for one shell diameter-to-wall thickness ratio.

From author's summary

Joints and Joining Methods

(See Revs. 1742, 1744)

Structures

(See also Revs. 1682, 1689, 1724, 1733, 1734, 1765, 1769, 1796, 1916, 1920, 1994)

1773. Baron, F., A pressure line concept for inelastic bending, *Proc. Amer. Soc. civ. Engrs.* **83,** EM 1 (*J. Engng. Mech. Div.*), Pap. 1157, 8 pp. Jan. 1957.

The concept of the pressure line, useful for arches and rigid frames, is developed for quickly estimating the effects of plasticity on the behavior of structural elements subjected to axial and flexural loads. An initial estimate, obtained by means of an elementary theory of mechanics, is adjusted to fit the conditions of plasticity.

From author's summary by A. H. Finlay, Canada

1774. Abbassi, M. M., The mathematical analysis of bow girders of any shape, *J. appl. Mech.* **23,** 4, 522-526, Dec. 1956.

By using parametric equations in which the parameter is the angle included between the tangent at any point on the bow girder and the tangent at the mid-point, the analysis of bow girders of shapes other than the circular arc can be treated mathematically. Exact and approximate formulas are given for symmetrical bow girders of any shape carrying a distributed load or two equal concentrated loads placed symmetrically with respect to the mid-point of the girder. From author's summary by M. Maletz, USA

1775. Sved, G., An electrical resistance network analogue for the solution of moment distribution problems, *Austr. J. appl. Sci.* 7, 3, 199-204, Sept. 1956.

Paper replaces frameworks with an electrical network. In this system structural members are represented by equivalent T-circuits with one branch grounded instead of by simple conductors. Into each of the three conductors a suitably selected electrical resistance is inserted. Ends of conductors corresponding to fixed-in ends of the structural members are grounded too. Loading of the frame is represented by currents fed into supply points corresponding to joints, end moments by current intensities measurable at the ends of conductors representing bar ends. In case of frames with fixed joints, the electrical analogy directly yields the end moments. In case of frames with movable joints, sway-balance is made by trial and error.

Paper effectively explains principles of the electrical analogy corresponding to steps of the Cross moment-distribution method.

P. Csonka, Hungary

1776. Turner, M. J., Clough, R. W., Martin, H. C., and Topp, L. J., Stiffness and deflection analysis of complex structures, *J. aero. Sci.* **23,** 9, 805-823, 854, Sept. 1956.

Authors present numerical method of direct stiffness calculation even for structures having relatively thick skins. Analysis yields stiffness influence coefficients for use in aeroelastic and other dynamic calculations. Using matric notation, method is particularly suited for automatic digital computers.

Considering joint displacements of a structure as unknowns, an infinite number of mutually compatible element deformations are possible. Actual deformations will be those also satisfying equilibrium. Complex structure, such as wing, is broken down into elements: flanges, cover plates, ribs and spars joined at selected nodal points. Number of elements and nodal points is limited by capacity of present-day computing equipment. Stiffness matrixes are developed for basic elements and a box beam analyzed in some detail, showing effects of shear lag. Useful bibliography and critical review of appropriate prior work is included.

C. M. Tyler, Jr., USA

1777. Masur, E. F., and Milbradt, K. P., On the carrying capacity of redundant structures, *J. appl. Mech.* **23,** 3, 403-406, Sept. 1956.

Paper is an extension of the first author's previous work to certain singular cases excluded in his original work in which certain nonlinear terms are included in predicting the behavior of redundant structures in the postbuckling range. A remarkable agreement between nonlinear theory and Masur's carefully conducted experimental results is shown. J. A. Cheney, USA

1778. Nehse, H., Moment distribution according to Kani in frames with interior hinges (in German), *Beton u. Stahlbeton.* **51,** 10, 234-236, Oct. 1956.

Slope distribution method by Kani (following others) is combined with moment-distribution method of Hardy Cross for special case of beam with interior hinge and supports fixed at one end and hinged at other end. By applying unit bending moment at freely supported end and calculating corresponding slope, carry-over factors and effective stiffness are determined for various interior hinge positions. Thereafter standard moment distribution can be used. G. G. Meyerhof, Canada

1779. Neal, B. G., Virtual work and the moment distribution method, *Engineering* **183,** 4740, 47-50, Jan. 1957.

Author explains how equations of equilibrium necessary to make sway corrections in moment-distribution method can be established using the principle of virtual work.

A. J. Bignoli, Argentina

1780. Pogany, W., The osmotic method of increasing concrete strength, *Civ. Engng., Lond.* **51,** 606, 1349-1351, Dec. 1956.

Article discusses the electro-osmotic method of increasing strength of concrete where water is drawn off from the interior of a liquid-plastic concrete. *Direct current* is used for causing a potential drop from an anode consisting of a round iron pipe to a cathode of perforated steel iron pipe. Water passes from the perforated pipe and is drawn off.

Certain precautions are required such as using the method before the concrete hardens, vibrating to keep minimum pore formation, holding the temperature due to the electric current to less than

50 C to prevent water evaporation and pore formation, maintaining the minimum colloidal content of 2 to 3 %, adjusting electrode distances to 1.7 volts per centimeter, and insulating the workmen from the job. Authors state it is applicable to thin sections, to prefabricated elements, and in winter where the temperature needs to be 30 to 50 F.

No experimental data are presented showing the superiority of the method; there are no sketches of experimental set-up, but tests were conducted at the Academy of Mining and Metallurgy in Cracow. H. Majors, Jr., USA

1781. Smith, G. M., and Young, L. E., Ultimate flexural analysis based on stress-strain curves of cylinders, *J. Amer. Concr. Inst.* **28,** 6, 597–609, Dec. 1956.

Authors present an interesting investigation on the strength of rectangular reinforced-concrete beams. They base the distribution of stresses in the compression zone of beams on mathematical analysis involving properties of materials used. This in itself is a deviation from the traditional assumption of some idealized stress distribution. The data on compressive strength of concrete were obtained from tests on 6-in. × 12-in. cylinders and that on strains from tests on cylinders and beams. Predictions of the total compressive force, the position of neutral axis, the ultimate moment, and the type of failure were favorably checked by actual tests.

This investigation opens the way for further analysis and predictions of strength based on determined properties of materials. M. V. Smirnoff, USA

1782. Pobyedonostsev, A. I., On the calculation of an anchored sheet-piling wall (in Russian), *Trudi Leningr. in-ta inzh. vodn. transp.* **21,** 207–217, 1954; Rev. no. 1126, *Ref. Zh. Mekh.* 1956.

A practical method is developed for the calculation of anchored sheet-piling retaining walls. The safety of the structure is determined according to the permissible loading and the limiting conditions. For a singly-anchored wall, two cases are examined: (1) The driving depth of the wall is insufficient, and the limiting condition arises when the wall can rotate about the point of attachment of the anchor; (2) the dimensions of the anchor are insufficient, and when the limiting load is applied, the excess is taken up by the wall itself.

For a doubly-anchored wall, two cases are also examined: (1) The top of the wall rotates towards the back-filling; (2) the same, but away from the filling.

Analysis of the methods of calculating sheet-piling walls has shown the necessity for more accurate consideration of the passive resisting forces in the upper part of the wall. The present practice of reducing the bending moment in a piling wall by 0.74 and increasing the anchoring force by 1.25 requires more accurate definition, depending on the possible amount of displacement of the top of the wall towards the back-filling.

(Misprint: on p. 210, in Eq. (4), $e_p/k_{\pi c}$ should be $e''_p/k_{\pi c}$).
Courtesy of Referativnyi Zhurnal G. I. Ter-Stepanyan, USSR
Translation, courtesy Ministry of Supply, England

1783. Chan, W. W. L., The ultimate strength and deformation of plastic hinges in reinforced concrete frameworks, *Mag. Concr. Res.* **7,** 21, 121–132, Nov. 1955.

By comparing the idealized assumption of plastic hinges concentrated at points and the actual spread of plasticity, the validity of the plastic hinge theory of reinforced-concrete frameworks is verified and the expressions for calculating the available plastic rotations are derived. Tests show that lateral binding considerably increases the stress-strain capacity of reinforced-concrete sections, and this can be employed to increase the rotation of critical plastic hinge zones. Further tests on struts provide information on the curvature distribution along plastic zones.
P. W. Abeles, England

1784. Johnson, J. W., Lateral tests on full-scale lumber- and plywood-sheathed roof diaphragms, ASME Spring Meet., Portland, Ore., Mar. 1956. Pap. 56-S-16, 14 pp. + 1 table + 13 figs.

Twenty full-scale wood roof diaphragms were tested in lateral loading to determine the influence of construction variables on resistance to static loads simulating wind, earthquake, and blast forces. The test results indicate that differences in assembly of diaphragms can cause great variation in strength and stiffness.
From author's summary

1785. Petrashen', V. I., The dynamic analysis of vertical retaining walls (in Russian), *Sbornik tr. Vses. n.-i. in-ta gidrotekh. i san-tekh. rabot* no. 5, 69–93, 1954; Rev. no. 1047, *Ref. Zh. Mekh.* 1956.

A discussion of the dynamic analysis of harbor structures (jetties and breakwaters) of the type of a vertical retaining wall, giving a mathematical method for such calculations, adapted for the sufficiently correct and simple determination of certain possible time variations of the loading by breaking waves, previously determined experimentally.

The body of the structure is assumed to be supported on an elastic foundation, and is treated as a system with three degrees of freedom, in the conditions of the two-dimensional problem.

The principal moment of the wave loads and the centrally acting horizontal and vertical components of the corresponding principal vector are treated as three independent loads, the time variation of which can be represented by a broken line. After this, each of these three component loads is treated as the successive superposition of a series of linearly increasing, time-proportional loads, counting from the corresponding apex $t = t_k$ of the approximating broken line. The safety coefficient of the structure in shear is defined as the minimum of the instantaneous coefficient of safety, determined by the expression

$$k = \frac{(Z_0 + Z_n)f}{X_0 + X_n}$$

where X_0 and Z_n are the initial values, and X_n and Z_n the dynamic increments of the horizontal and vertical reactions, respectively, of the foundation; f = coefficient of friction.

This formula is generalized for the case of discontinuously varying loads and concentrated impulses. A numerical example is appended. O. A. Savinov, USSR
Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1786. Darkov, A. V., The stress condition in the trapezoidal mass of an embankment produced by the action of an external load (in Russian), *Sbornik statey Vses. zaoch. politekh. in-ta* no. 10, 57–72, 1955; Rev. no. 1063, *Ref. Zh. Mekh.* 1956.

The problem is investigated of the stress conditions in a symmetrical trapezoidal earth embankment subjected to a uniformly distributed load. The weight of the structure is neglected. In the solution, the trapezoid is substituted by a wedge with a concentrated force at the apex, this wedge being subsequently resolved into a number of "secondary wedges," which are substituted by hinged bars. The resulting bar frame is calculated by the method of forces. The author makes no reference to the work of B. G. Galperin[*Sbornik tr. Leningr. in-ta Inzh. put. Soobshcb.* no. 99, 1929] where the solution is given in the most general form.
Courtesy of Referativnyi Zhurnal A. M. Kochetkov, USSR
Translation, courtesy Ministry of Supply, England

1787. Hirai, A., Aerodynamic stability of suspension bridges under the influence of wind loads (in German), *Bauingenieur* **31**, 11, 402–408, Nov. 1956.

Paper presents theoretical investigation of forced vibrations caused by variable wind velocity by introducing comparable value of "dynamic increment," similar to the amplitude of vibration and its frequency. Results of these investigations are compared with wind-tunnel tests at University of Osaka, which are thoroughly described, and derivations made by Fr. Bleich, with satisfactory conformity. It was found that each type of suspension bridge is subject to different wind velocity under which the vibration of stiffening girders becomes critical; in many cases vibrations will slow down when the wind velocity increases beyond that critical intensity until a much higher velocity occurs. Basically, the critical velocity depends on rigidity of the girders against bending and torsion, and it is greatly influenced by the mass of deck structure and, consequently, the tension in the cables. For these reasons, a deck structure of reinforced concrete has a greater aerodynamic stability than if built of steel. Tests performed by the author proved also that whirlwind and its uplift action seriously affect the stability of a suspension bridge.

Reviewer's opinion is that author should have applied his theory to some well-known suspension bridges in the U.S.A, with reference to theoretical and experimental research by leading engineers, such as Steinman, Maher, Becker, and others.

J. J. Polivka, USA

1788. Lin, T. Y., Cable friction in post-tensioning, *Proc. Amer. Soc. civ. Engrs.* **82**, ST 6, (*J. Struct. Div.*), Pap. 1107, 13 pp., Nov. 1956.

1789. Reichert, T. M., Plate coolers (in Dutch), *Ingenieur* **68**, 41, Ch. 61–Ch. 72, Oct. 1956.

A survey is given of the considerations which may lead to the application of plate coolers. Especially for manufacture from stainless steel, the use of sheets instead of tubes may result in a saving of investment costs.

The calculation and construction of two types of plate coolers are discussed in detail. From author's summary

1790. Anonymous, Heat exchangers made by a new method, *Engineering* **182**, 4726, p. 445, Oct. 1956.

Rheology (Plastic, Viscoplastic Flow)

(See also Revs. 1692, 1758, 1761, 1763, 1768, 1783)

1791. Prager, W., Total creep under varying loads, *J. aero. Sci.* **24**, 2, 153–155 (Readers' Forum), Feb. 1957.

Neglecting elastic and primary creep deformation, boundary-value problems for creep are considered in the form: velocities of the points of part of surface vanish at all times and surface tractions for the rest of surface are given in product form $T_i(x)\,\phi(t)$, where x stands for the coordinates of a genetic point and t denotes the time. Secondary creep-rate tensor is assumed in its most general form as a function of second- and third-order invariants of stress deviation tensor. It is shown that solution of boundary-value problem as regards stresses, velocities, and displacements throughout the body has similar product form as surface tractions. Influence of exponent of Norton's creep law on total creep deformation for different pulse form $\phi(t)$ is discussed.

F. K. G. Odqvist, Sweden

1792. Mendelson, A., Practical solution of plastic deformation problems in the elastic-plastic range, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-202, 38 pp.

Several problems of deformation theory of plasticity are solved by successive approximations. Equations are written as relations between *total* strains and integrals over *plastic* strains. Assuming suitable initial values of plastic strains (zeroth approximation), corresponding total strains are calculated from said relations. Next, plastic strains corresponding to calculated total strains are obtained from stress-strain relations (first approximation), and process is continued. Convergence may be accelerated by special devices. Four examples illustrate range of method.

Author mentions similarity of his method to Ilyushin's treatment of thin shell ["Some problems in the theory of plastic deformations," *Prikl. Math. Mekh.* **7**, p. 245, 1943].

W. T. Koiter, Holland

1793. Oding, I. A., and Burdukski, W. W., Damage of metal under creep (in German), Deformation and flow of solids, Colloquium Madrid, Sept. 26–30, 1955, 298–303. Berlin, Springer Verlag, 1956.

Authors discuss relative damage in metals under creep conditions in terms similar to those used for fatigue damage under cyclic stresses: stress level, time, surface defects, etc. Their use of a stress-time plot and subsequent summing of the relative damage from each of several stages of stress and time as "destruction" (fracture), or $D_1 + D_2 + \ldots = 1$, is effectively a "Miner criterion" for creep. To support this procedure, experimental data are given in the form of a material characteristic m, expressing damage as $D_1 = (t_1/t_2)^m$, where t is time at a given stress. Relations for the creep velocity are then derived leading to the von Ludwick equation: $d = kA_1 e^{as} t^m$, where velocity equals $A_1 e^{as}$, s and d are stresses, and k, A_1 and a are constants; said to be the relation in best agreement with experimental data. Relations are also given between number of defects, velocity, time, stress and m.

Even though actual data are given, paper appears to be only a short portion of continuing (?) work, and this reviewer is unable to form a definite conclusion as to its usefulness or application. Particularly, the reference to "number" of defects seems incomplete.

C. C. Osgood, USA

1794. Le Boiteux, H., and Pauthier, Suzanne, General behavior of viscous materials in the elastic and plastic ranges (in French), *ONERA NT* 54, 23–30, Nov./Dec., 1956.

Equations governing the viscoelastic deformation of solids, presented at Eighth Congress of IUTAM in Madrid (1952), have been solved more accurately to give the laws of deformation in the two cases of imposed stress and imposed strain. Behavior under variable and periodic excitation leads to apparent Young's moduli and Poisson coefficients which depend upon frequency, and are related to sonic velocity. Equations for simultaneous study of strain and birefringence are applied to data on plexiglass. Relationship between load and delayed rupture is studied.

I. M. Krieger, USA

1795. Verma, P. D. S., Hypo-elastic pure flexure, *Proc. Indian Acad. Sci.* (*A*) **44**, 4, 185–193, Oct. 1956.

Author obtains a solution of the equations for hypo-elastic bodies of grade zero. It is intended to describe " ... steady bending of a narrow but thick rectangular plate of constant density into a region of circular form ...". The solution seems appropriate for expansion or contraction of a cylindrical tube. The motion considered cannot effect the change of shape envisaged by the author, if the reviewer interprets the quoted statement correctly, so the problem set seems not to have been solved.

J. L. Ericksen, USA

1796. Finzi, L., Conditions for a return to elastic behavior of plastically deformed elements with increasing loads (in Italian), *G. Gen. civ.* **94**, 4, 241–249, Apr. 1956.

In a statically indeterminate structure of elastic-plastic material a relative change of the state of stress takes place when the first element reaches the yield point. Conditions are established under which the strain, and therefore the stress, in this plastically deformed element can decrease while the load is still increasing. In a truss of perfectly elastic-plastic material this return to elastic-plastic behavior can occur only when a second element reaches the yield point. The described phenomenon depends essentially on the statical interaction of the two first plastically deformed members. F. Stussi, Switzerland

1797. Schultz-Grunow, F., Viscosity and time effects in the nonlinear region (in German), Deformation and flow of solids, Colloquium Madrid, Sept. 26–30, 1955, 279–297. Berlin, Springer Verlag, 1956.

Article, primarily a review, shows successful applications of dimensional analysis to rheological data obtained by various methods on a number of non-Newtonian and viscoelastic materials.

Reviewer considers author's criticism of equations of Mooney and of Roberts on normal stress to be groundless. Criticism is that equations neglect past history of sample. However, equations were offered and were applied only for steady-state, continuous simple shear, in which case all the significant past history is completely determined by the particular steady state. Author's derivation of an equation for normal stress considers only one of at least two factors of equal importance. M. Mooney, USA

1798. Ainbinder, S. G., and Klokova, E. F., On the formation of cohesion of metals during joint plastic deformation (in Russian), *Zh. tekh. Fiz.* **25**, 13, 2356–2364, 1955 (translated from Russian by M. D. Friedman, 572 California St., Newtonville 60, Mass., 12 pp.).

Failure, Mechanics of Solid State

(See also Revs. 1798, 1812)

1799. Head, A. K., The propagation of fatigue cracks, *J. appl. Mech.* **23**, 3, 407–410, Sept. 1956.

Author extends a former theory on the rate of growth of fatigue cracks to include the case of large stresses and points out several inconsistencies in the earlier theory. The extended theory deals entirely with crack propagation and not crack initiation.

A mechanism of crack growth is discussed which involves assuming a crack in an elastic solid. The applied stress leads to a stress concentration at the crack tip resulting in plastic deformation, elastic constraint, and yielding in the surrounding material. Reversing the stress will cause further deformation and strain-hardening near the crack tip. The rate of strain-hardening may not be sufficient in one case to reach the rupture strength in the critical area ahead of the crack. This condition leads to elastic behavior. However, if the rupture strength is reached the crack propagates. The growth of a crack is thus assumed to occur by exhaustion of ductility in the material ahead of the crack. In an idealized model consisting of a chain of three types of mechanical elements, the strain-hardening rate is assumed constant and the fracture strain is defined as the difference between the rupture and yield strengths divided by the strain-hardening modulus. Limited experimental evidence implies that localized ductility to rupture under fatigue loading is of the order of 100 to 1000 times greater than the over-all strain measured in tension. The length of the elastic elements through which the stress is applied to the plastic elements and which constitute the elastic constraint is assumed as half the instantaneous crack length. Assumed also are elastic-shear elements which transfer stress down the chain of elements.

Mathematical solutions for crack growth in terms of applied stress, yield and rupture strengths, and number of cycles for low and large stresses are presented. The relations for both stress levels are found to be of the same form. It is also implied that the same is true for intermediate stresses.

F. Garofalo, USA

1800. Kawada, Y., and Kodama, S., A criterion on fatigue failure of metals, *Mem. Fac. Technol. Tokyo Metrop. Univ.* no. 6, 7–15, 1956.

Authors propose criterion for fatigue failure under combined steady and alternating stress in following general form: $m_1\sigma_\phi + m_2 r_\phi + m_3 r_w = K$. In this m_1, m_2, m_3, and K are constants depending on material and stress conditions, and σ_ϕ, r_ϕ, and r_w are maximum normal, maximum shear, and alternating shear stresses acting on plane at angle ϕ. Value of ϕ is determined so as to make left-hand side of equation a maximum. Formula is applied to following cases: (1) cohesive failure under repeated stress, (2) sliding failure under repeated compressive stress, and (3) the same under repeated tensile stress. Results are compared with fatigue tests on cast-iron, duralumin, and mild steel, using various values for constants. Use of formula shows an increase in alternating stress with decrease in mean stress.

A. M. Wahl, USA

1801. Findley, W. N., and Mathur, P. N., Modified theories of fatigue failure under combined stress, *Proc. Soc. exp. Stress Anal.* **14**, 1, 35–46, 1956.

Experimental data on combined stress fatigue failure were reviewed and compared with classical theories for yielding. These theories were modified for anisotropy of the material and for the complementary normal stress to represent the data more closely. Materials on which combined bending and torsion data were available were divided into three classes, and it was found that different equations were necessary to represent the behavior of the different classes. Modified expressions were developed to represent fatigue failure under other combined stress states.

J. A. Bennett, USA

1802. Walker, P. B., Fatigue of aircraft pressure cabins, Fifth International Conference, Los Angeles, June 20–23, 1955, 353–381. New York, Institute of the Aeronautical Sciences.

Author gives a general account of the Comet fatigue tests. First part of paper deals with the general stress pattern in the cabin due to internal pressure stress raisers, skeleton, etc. Second part concerns the stresses not due to pressure-gusts, landing, etc. Finally, there is a description of the RAE test apparatus used for the Comet and the newer one designed for Britannia and other A/C. There is also a description of some of the failures that were produced on a Comet fuselage.

M. P. White, USA

1803. Marin, J., Significance of material properties in design for fatigue loading. Part I. Simple static stresses. Combined static stresses, *Mach. Design* **29**, 2, 88–94, Jan. 1957.

1804. Marin, J., Significance of material properties in design for fatigue loading. Part II. Generalized failure theories. Design for static stresses. Design for static stress concentration, *Mach. Design* **29**, 3, 95–99, Feb. 1957.

1805. Raithby, K. R., and Longson, Jennifer, Some fatigue characteristics of a two spar light alloy structure (Meteor 4 tail-

plane), *Aero. Res. Counc. Lond. curr. Pap. no.* 258, 8 pp. + 7 tabs. + 18 figs., 1956.

Results are given for fatigue tests on sixty-one Meteor tail-planes, treated as representative small-scale wing systems and tested under a variety of loading conditions. The object of the investigation was to study the fatigue characteristics of a typical aircraft structure; in particular, the effects of the mean load and alternating load on the endurance. The effects of preloading, periodic overloading, and low temperatures were also investigated.

Endurance curves are given for different mean loads; the results indicate that, for a given alternating load, the endurance is roughly inversely proportional to mean load. Substantial improvements in endurance may be obtained by preloading and by periodic overloading. The endurance at low temperatures is higher than at room temperature. From authors' summary

1806. Starkey, W. L., and Marco, S. M., Effects of complex stress-time cycles on the fatigue properties of metals, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-1, 8 pp.

An investigation was conducted to determine the effects of complex stress-time cycles on the fatigue properties of metals. The uniaxial stresses studied were complex in the sense that their stress-time patterns may be analyzed as composed of several harmonic components. Four theoretical design methods, and the results of an experimental investigation involving complex stresses are presented. Test results are compared with theoretical predictions. From authors' summary

1807. Hall, W. J., Mosborg, R. J., and McDonald, V. J., Brittle fracture propagation in wide steel plates, *Welding J.* **36,** 1, 1s-8s, Jan. 1957.

The propagation of brittle fracture in 2 and 6 ft wide steel specimens was studied. Experimental techniques are given for testing at various temperatures and stress conditions, and among the variables recorded are crack velocity and strain response. Examples of test data are shown and some analysis carried out. Attempts to correlate crack velocity and fracture appearance have not been successful. Crack velocities for the majority of tests were in the range of 3000 to 4000 fps, although velocities as high as 5900 fps were recorded.

The paper is a progress report and work is still in progress.

A. D. Schwope, USA

1808. Mylonas, C., Drucker, D. C., and Isberg, L., Brittle fracture initiation tests, *Welding J.* **36,** 1, 9s-16s, Jan. 1957.

Exploratory tests were made to produce brittle fractures at loads less than the virgin yield point. Welded and unwelded notched steel plates with various prestrains were pulled at several low temperatures. Transversely prestrained plates with punched notches fractured consistently below the static yield load. In two cases plates failed at stresses as low as approximately 70% of nominal yield strength. T. J. Dolan, USA

1809. Roesler, F. C., Brittle fractures near equilibrium, *Proc. phys. Soc. Lond. (B)* **69,** 442, 981-992, Oct. 1956.

For brittle materials, according to Griffith's hypothesis, the balance of surface energy and mechanical energy controls the fracturing process. The cone fracture in silicate glass produced by an indenter is stable and the speed at which a fracture spreads can be controlled. Results of experiments with glass together with the appropriate theory are given. With some qualifications, experimental results are found to be in agreement with the Griffith hypothesis. The procedure developed is recommended for other brittle materials for determining the specific fracture energy.

E. P. Popov, USA

1810. Tipper, C. F., The study of fracture surface markings, *J. Iron Steel Inst. Lond.* **185,** 1, 4-9, Jan. 1957.

A detailed investigation of a fractured plate from an oil-storage tank has shown that the surface markings are due to the arrest and re-initiation of the fracture. Cracks which are approximately parallel and staggered are joined by shear of the bridges of metal separating them. Discontinuities, or steps, are left on the fractured surfaces since the individual fracture zones are at different levels and tend to overlap.

This mechanism of breakdown can occur on a microscopic scale and on a gross scale wherever the fractures are chiefly brittle.

From author's summary

Material Test Techniques

(See Revs. 1772, 1793)

Mechanical Properties of Specific Materials

(See Revs. 1805, 1806, 1811, 1814, 1818)

Plasticity, Forming and Cutting

(See also Revs. 1713, 1714)

1811. Majors, H., Jr., Influence of cold drawing SAE 1018 steel upon brittle transition temperature, *J. Technol.* **1,** 1, 57-80, Jan. 1956.

Impact tension tests at various temperatures using a pendulum-type machine are reported. Cylindrical specimens with a square section notch machined in them were attached in series with a weighbar fitted with strain gages. The amplified signal displayed on an oscilloscope enabled observations of the time-dependent load trace during impact to be obtained. This was found to change in shape as the temperature was lowered, and the criterion of brittle fracture was taken to be when the trace first became triangular, indicating the disappearance of plastic flow.

The temperature of specimens was measured immediately prior to fracture by a thermocouple placed in an axial hole drilled to within 3/8 in. from the notch.

The effect of cold-drawing was found to produce a considerable increase in the transition temperature. The influence of the orientation of the specimen with respect to the drawing direction was also investigated. It is concluded that the directional effect has a marked influence on the properties in the ductile region but is very small in the brittle region.

Comparison of the present results with the small amount of data available is made. F. Ellis, England

1812. Grainger, J. A., The deep drawing and spinning of sheet metal, with particular reference to non-ferrous materials, *J. Inst. Metals* **84,** 133-146 + 28 figs., 1955-1956.

Recent developments in machines and methods for the deep drawing and spinning of sheet are reviewed. Particular attention is devoted to techniques, such as marforming, hydroforming, and flow-turning, which provide an inexpensive means of producing small quantities of parts, and to their application to nonferrous metals. Lubrication is also discussed.

From author's summary

1813. Thomsen, E. G., and Frisch, J., Experimental and theoretical pressures and velocity fields for various lead extrusions,

ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-45, 6 pp.

Extrusion pressures and velocity fields were determined for inverted extrusion processes of commercially pure lead. The extrusion ratios were varied from 1.51 to 18.5 (33.7% to 94.6% reduction). It was found that, for both low and high friction at cylinder wall and at die surfaces, qualitative agreement exists between slip-line solutions and experiment.

From authors' summary

1814. Oleynik, N. V., The influence of high-speed machining on the endurance limit of steel (in Russian), *Nauch. Zap. Odessk. politekh. in-ta* **1**, 1, 33-43, 1954; Rev. no. 1203, *Ref. Zh. Mekh.* 1956.

Results are given for the determination of the fatigue strength of samples machined in a lathe at cutting speeds of 150-450 mpm, and a feed of 0.08-0.16 mm/revolution, in the annealed and unannealed states.

Author comes to the conclusion that, with increasing cutting speed, the endurance limit for peened samples increases for all feed values, but not as highly as for untreated samples.

With increasing cutting speed, on the one hand, the quality of the surface finish is improved, which favorably influences the value of the fatigue limit; on the other hand, the residual stresses increase, unfavorably affecting the strength of the peened samples.

Courtesy of Referativnyi Zhurnal V. P. Semenov, USSR
Translation, courtesy Ministry of Supply, England

1815. Nekrasov, S. S., An investigation of the forces acting in the cutting of coal (in Russian), *Ugol* no. 11, 18-24, 1954; Rev. no. 1257, *Ref. Zh. Mekh.* 1956.

The investigation was made on a planning machine with a maximum stroke of 400 mm and cutter speed of 27.3, 35.0, and 50.5 m/min. The three-component cutting forces P_x, P_y, P_z were measured by a specially designed, three-component dynamometer. The cutter for hard coals was a GOST 4617-49 type with a limiting angle of $\gamma = 14°$, a relieving angle of $\alpha = 6°$, and a width of cutting edge of $b_0 = 7.5$ mm; while for soft coals, the GOST 4615-49 cutter had an angle of $\gamma = 20°$, $\alpha = 25°$, and a value of $b_0 = 3.5$ mm.

Cutting conditions were controlled by an electric strain gage and MPO-2 oscillograph. Two types of coal were tested: Donets (80% vitrain, 1-2% pyrite, rest, xylofusain and xylene; the coal granules were cemented by calcite); and a brown, sub-Moscow coal (70% durain, 20% clayey particles, 5% fusain and isolated, large pyritic inclusions).

Samples were first tested in compression. It should be noted that the results of these tests showed a decisive relationship between the endurance strength σ_d, and the size of the sample; as follows, also, from the statistical theory of brittle fracture. For instance, in tests on a sample with an area of $F = 1440$ mm², $\sigma_d = 2.3$ kg/mm², but with $F = 100$ mm², $\sigma_d = 5.4$ kg/mm².

(1) Depth of cut a. The test data showed good agreement with the author's theoretical calculation by the formula

$$P_{z\,max} = k\sigma_{d\,max}\, a^n$$

($k = 7$, $n = 0.87$ for cutter GOST 4617-19, and $k = 4$, $n = 1$ for cutter GOST 4615-19 and GOST 4616-49). No derivation of this formula is, however, given in the article.

(2) Cutter setting angle. The experiments showed that with increase of the setting angle from 0° to 45°, the component $P_{z\,max}$ decreases, while $P_{y\,max}$ and $P_{x\,max}$ increase.

(3) Cutting angle δ. With increased cutting angle for Donets coal from 60° to 90°, the components $P_{z\,max}$ and $P_{y\,max}$ increase by about 30%.

(4) Cutter wear. For very blunt cutters, $P_{z\,max}$ is about twice that for sharp-ground cutters.

(5) Cutting speed. The experiments showed that this has practically no influence on $P_{z\,max}$.

(6) Pyrite inclusions materially influenced the maximum values of the cutting forces. This aspect has not been fully investigated.

(7) Weathering markedly decreased the mechanical strength and cutting force for sub-Moscow coal.

Courtesy of Referativnyi Zhurnal G. S. Shapiro, USSR
Translation, courtesy Ministry of Supply, England

1816. Bunin, M. V., On the physical and mechanical characteristics of the stone-crushing process (in Russian), *Trudi Kharkovsk. avtomob.-dor. in-ta* no. 17, 87-95, 1954; Rev. no. 1259, *Ref. Zh. Mekh.* 1956.

The results are given of an experimental investigation of the process of stone-crushing, and the physical significance of the phenomenon of stone-cleavage is explained. In testing samples—of shell limestone, cement slurry and paraffin—the formation of a drop-shaped region under the contact surface, consisting of comminuted, pulverulent material, was observed. This destruction of the zone is explained by the appearance of internal microstresses due to irregular compression; when these attain their limiting value, the individual grains of the stone fracture and become detached. The pressures arising in the material crushed to powder in the drop-shaped zone, which resemble hydraulic pressure effects, cause the region to assume the form of a wedge, as a result of the action of which cleavage of the stone takes place.

Deviations from the laws of mechanical similarity have been observed, on which coarse and medium crushing theory had hitherto been based. A. S. Dmitriev, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1817. Dyrkacz, W. W., and Reynolds, E. E., Vacuum-melted alloys for forged parts, *Prod. Engng.* **28**, 2, 143-145, Feb. 1957.

1818. Grala, E. M., Further investigation of the feasibility of the freeze-casting method for forming full-size infiltrated titanium carbide, *NACA TN* 3769, 19 pp., Oct. 1956.

A method of casting full-size cermet turbine blades from titanium carbide was investigated. An extremely thick slip of titanium carbide was prepared with a small amount of binder, cast into a mold by vibration, centrifuged, and frozen to retain the shape of the mold. The casting was then dried in an absorbent sand and sintered by conventional means. The porous casting could then be infiltrated with a nickel- or cobalt-base alloy. Densities and radiographs of the blade prior to infiltration were used as criteria for soundness. From author's summary

Hydraulics; Cavitation; Transport

(See also Revs. 1715, 1833, 1974)

1819. Bull, T. H., The tensile strengths of viscous liquids under dynamic loading, *Brit. J. appl. Phys.* **7**, 11, 416-418, Nov. 1956.

Under similar conditions of transient loading, the cavitation thresholds of syrup and olive oil are $130 \times$ dyne/cm² and 29×10^6 dyne/cm², respectively. For fluids with a viscosity (η) in the range 0.01 to 400 P the cavitation threshold pressure P_c is given by the empirical relation $P_c = k\,\eta^{0.2}$. This result can be interpreted on the basis of the growth of cavitation nuclei in viscous liquids subjected to transient stresses.

From author's summary by H. H. Anderson, Scotland

1820. Li, W.-H., Open channels with nonuniform discharge, *Trans. Amer. Soc. civ. Engrs.* **120,** 255-280, 1955.

Author has treated the problem of determining the flow in surface profile for side-channel spillways, wash-water troughs, and similar channels carrying discharges which increase along their length. The approach using the principle of conservation of momentum is essentially the same as that used by J. Hinds [title source **89,** 881-939, 1926], and T. R. Camp [title source **105,** 606-637], but the treatment is extended to include more general cases, such as flow in channels with sloping side walls or supercritical flow. Author's presentation is clear and concise, and in a form useful for design, but reviewer considers paper weak in not discussing previous investigations in this subject, such as Citrini, AMR **1,** Rev. 1483, and others as noted in written discussion of paper.

N. H. Brooks, USA

1821. Filchakov, P. F., Determination of the constants of the Christoffel-Schwartz integral in the hydromechanical calculation of a two-channel spillway dam (in Russian). *Ukrain. Mat. Zh.* **6,** 4, 463-475, 1954; Rev. no. 312, *Ref. Zh. Mekh.* 1956.

An approximate method is explained for determining the parameters of a Christoffel-Schwartz integral ("reflection constant" according to author's terminology) in the hydromechanical calculation of filtration, based on a flat spillway dam with two channels of unequal length and with an absolutely impenetrable front apron, at different markings of the upper and lower water (at $T = \infty$ and $T \neq \infty$). The approximation method indicated is based on the use of two systems of equations (I and II). System I determines the reflection constants in a precise solution of the problem. System II determines the reflection constants when using an approximate method of making the spillway two-dimensional. In the first approximation, the reflection constants are determined from system II according to the given dimensions of the spillway. According to the reflection constants found in the first approximation new dimensions of the spillway as a first step are determined from System I. Correcting the given dimensions of the spillway by the value of the deviation between the given dimensions and the dimensions determined in the first step by system II, author finds values of the reflection constants in the second approximation, and further from system I the new dimensions of the spillway in the second step, etc. Calculation of the successive approximations is continued until the given dimension of the spillway agrees with the dimensions obtained in the last step within the limits of the accepted accuracy of the calculations. For illustration of the above method of determining the reflection constants, several numerical examples are examined. Evidence of the convergence of the process of successive approximation when determining the reflection constants is not given in the work.

Courtesy of Referativnyi Zhurnal S. N. Numerov, USSR
Translation, courtesy Ministry of Supply, England

1822. Smyslov, V. V., Calculation of the curvature of the free surface of an open spillway with a wide apron (in Russian), *Izv. in-ta gidrol. i girrotekh. Akad. Nauk USSR* **11,** 31-39, 1954; Rev. no. 819, *Ref. Zh. Mekh.* 1956.

A method of construction of the curve of the free surface of the flow in an open spillway with a wide apron is examined. The analysis is based on the Bernouilli equation of a potential flow but with correction for the effect of centrifugal forces acting on account of the vertical curvature of the surface. Author finds that the motion in a spillway with a wide apron can be described by the energy and continuity conditions without correction for losses only for the case of a flow coefficient $m < 0.385$ and $h < h_{Kr}$, but not for $m = 0.385$ and $h = h_{Kr}$ as has hitherto been considered.

An expression is given characterizing the tangent of the angle of inclination of the free surface of a curvilinear flow to the horizontal, as well as a curve of relative depths on the apron, depending on the value of the said angle, and the flow coefficient m.

On the basis of numerical integration of the author's derivation of the Bernouilli equation for the case of a curvilinear flow, curves are plotted of the free surface of the spillway flow, both for the case of a horizontal section of parallel flow and of a single surge.

Courtesy of Referativnyi Zhurnal A. R. Berezinskii, USSR
Translation, courtesy Ministry of Supply, England

1823. Knapp, R. T., Accelerated field tests of cavitation intensity, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-57, 6 pp.

Paper describes a new technique for measuring the intensity of the cavitation attack in a piece of hydraulic equipment operating in the field, and presents the results and conclusions of a preliminary trial of this method in a 30,000-kw hydraulic turbine. This technique has been referred to as an accelerated test because the time required for the test run is measured in minutes, and by careful planning the total outage time required for installation and removal of the test plates is short. From author's summary

Incompressible Flow: Laminar; Viscous

(See also Revs. 1819, 1850, 1853, 1854, 1857, 1860, 1883, 1923, 1925, 1949, 1963)

1824. Kettleborough, C. F., The sector-shaped pad, *J. appl. Mech.* **23,** 4, 584-586, Dec. 1956.

Calculating the operating conditions of a sector-shaped pad, author follows the same approximation method which Boegli used in the case of a finite slider. It is based on the two following assumptions: (1) The pressure distribution can be represented by a product of a function depending only on the coordinate in the direction of motion and a function depending only on the width coordinate; (2) the first-mentioned function is the same as that for an infinite slider. In his calculation, author assumes that viscosity varies proportionally to the film thickness.

First, in Reynolds equation transposed for polar coordinates, all quantities are replaced by nondimensional quantities. Thus $\theta_1 = \theta\phi$(ϕ = angle subtended by radial edges of pad) is substituted for the angular coordinate θ, and $r_1 = \ln(r/r_0)/\rho$ [r_0 = inner radius, r_2 = outer radius, $\rho = \ln(r_2/r_0)$] for the radius r. Just so, nondimensional quantities are introduced for film thickness and viscosity. Then $p = \bar{A}e^{2\rho r_m}F(\theta_1)G(r_1)$ is put for the pressure. In this expression r_m is the value of r_1 for which $G(r_1)$ becomes a maximum. According to assumption (2) the pressure distribution at $r_1 = r_m$ shall be the same as that for a pad of infinite width. Therefore it is assumed that for $r_1 = r_m$ all derivatives of p with regard to r_1 vanish. Thus a differential equation for $F(\theta_1)$ is obtained. This is solved and the point $\theta_1 = \theta_m$ is determined at which $F(\theta_1)$ becomes a maximum. Then $G(r_1)$ can be calculated from Reynolds equation set up for $\theta_1 = \theta_m$. Finally, the quantity r_m appearing in the solution is determined from the condition that $G(r_1)$ becomes a maximum for $r_1 = r_m$. With $F(\theta_1)$, $G(r_1)$, and r_m, the pressure distribution is known, and load, friction force, and friction number can be computed.

Author performs the numerical calculation for a special example and compares the results with results which Boswall and Christopherson obtained by following more exact but much more difficult and tedious methods. U. Rost, Germany

1825. Ezekiel, F. D., and Paynter, H. M., Computer representations of engineering systems involving fluid transients, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-120, 10 pp.

This paper concerns the use of computers to simulate fluid

equations involving the operations of addition, multiplication, functional dependency, selection, rectification, integration, and pure delay. The elements in pneumatic and hydraulic systems are classified into transducers, modulators and transmitters, which are analyzed in terms of resistance, capacitance, and inertance. These concepts are used to obtain computer block diagrams for some engineering applications. R. Oldenburger, USA

1826. Sanyal, L., On the flow of a viscous liquid between two co-axial circular cylinders under a periodic pressure-gradient, *J. Technol.* **1,** 1, 43–47, June 1956.

Navier Stokes equations are solved for axial flow of a liquid between concentric cylinders where the pressure drop fluctuates periodically with respect to time. Solution encompasses quasi-steady case and also high-frequency case where boundary-layer effects appear. R. A. Burton, USA

1827. Rastogi, R. P., and Pandya, T. P., One-dimensional inviscid flow through a rocket nozzle, *J. chem. Phys.* **25,** 5, 1009–1012, Nov. 1956.

A thermodynamic theory of one-dimensional nonisentropic flow through a rocket nozzle is developed by using a parameter called "extent of reaction" introduced by de Donder. The formalism makes it possible to compute the exhaust velocity and cooling rate when there are significant departures from chemical as well as internal equilibrium.

It is shown that the cooling rate at the throat is likely to increase when the departures from equilibrium become significant.

From authors' summary

1828. Prussov, V. M., An approximate solution for some problems of unsteady fluid flow (in Russian), *Uchen. Zap. Karelo-Finsk. un-ta* **3,** 4, 77–109, 1954; Rev. no. 818, *Ref. Zh. Mekh.* 1956.

The unsteady, slowly varying flow of a fluid in a prismatic duct in the absence of resisting forces is examined. Applying the method developed by S. A. Khristianovich [*Prikl. Mat. Mekh.* **11,** no. 2, 1947], an approximate solution is given for the equations of unsteady motion, in the form of an analytical expression.

Cases are investigated of rectangular and triangular channels, the solution obtained by graphical analysis being correlated with that found by the author analytically, and the adequacy of the approximation is demonstrated.

Courtesy of Referativnyi Zhurnal V. A. Karpychev, USSR
Translation, courtesy Ministry of Supply, England

1829. Matinyan, S. M., A method of measuring a three-dimensional velocity field in an unsteady flow in conditions of sink formation (in Russian), *Izv. Akad. Nauk ARMSSR, Ser. Fiz.-Mat., estestv. i tekh. n.* **8,** 2, 63–73, 1955; Rev. no. 990, *Ref. Zh. Mekh.* 1956.

A method is suggested for measuring the instantaneous values of the velocities in an unsteady flow, consisting in the cinematography of illuminated floats.

Such a float is constituted by an electric light bulb suspended on a thread. The volume density of this bulb in a special protecting net is the same as that of water.

The position of the lamp is recorded in two projections: from the side wall of the tank or trough, and from the downstream section of the weir intersecting the flow (flow from under the weir). This second projection is reflected by means of a mirror into the cine-camera simultaneously recording the first projection.

The cine films are evaluated in a standard enlarger for the "FED" photographic camera. The method of measuring is described. No results of velocity measurements are given.

Courtesy of Referativnyi Zhurnal E. M. Minskii, USSR
Translation, courtesy Ministry of Supply, England

1830. Punnis, B., On the differential equation of Blasius for the plate boundary layer (in German), *Arch. Math.* **7,** 3, 165–171, 1956.

The differential equation of Blasius is dealt with from a mathematical point of view. It is shown that the singularity is a simple pole, and a method is given to calculate the singular point with arbitrary accuracy. The result is of no significance for the boundary-layer problem as the singularity is outside the range of variables defined from physical considerations.

T. R. Gullstrand, Sweden

1831. Ledochowski, W., An analytic method of locating leaks in pressure pipe-lines, *Trans. S. African Instn. civ. Engrs.* **6,** 12, 341–344, Dec. 1956.

1832. Kayan, C. F., and Balmford, J. A., Analysis of a process-fluid-flow network by electrical analogy, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–187, 6 pp. + 3 tables + 9 figs.

In a process-fluid-flow network of numerous interconnected branches of different proportions, the determination of the flow distribution by calculation is difficult because of the pressure-drop versus flow-rate characteristics of each individual component of the complex. Not only does the pressure drop vary with the effective pipe dimensions and surface condition, for a given fluid, but also markedly with the flow rate, and usually, in turbulent flow, with flow rate modified by some exponent with value on the order of 2.0. The concept of flow "resistance," to represent opposition to fluid flow, is a useful tool. The pressure drop in any process branch line may be considered as proportional to the product of the flow rate and the pipeline "resistance," and for turbulent flow the resistance itself may be considered a function of the flow rate. Thus, the flow characteristics of a network may be simulated by electrical analogy, with the electrical resistance in each branch simultaneously adjusted to some desired function of the electrical current. Voltage and current determinations at given points are representative of the corresponding fluid pressure and flow rates. An illustrative process-plant network with numerous branches and discharge points is analyzed, with predictions of flow distributions and pressures.

From authors' summary

1833. Kittridge, C. P., and Rowley, D. S., Resistance coefficients for laminar and turbulent flow through one-half-inch valves and fittings, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–190, 5 pp. + 9 figs.

Apparatus and test procedures to determine resistance coefficients for laminar and turbulent flow through 1/2-in. I.P.S. valves, fittings, and fabricated bends are described. Resistance coefficients are given as functions of Reynolds number. Results of the investigation are discussed briefly.

From authors' summary

1834. Rhoden, H. G., Effects of Reynolds number on the flow of air through a cascade of compressor blades, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2919, 34 pp., 1956.

The experimental work consisted of the separate testing of three cascades of axial-flow compressor blades of camber angles 20°, 30°, and 40°, respectively. Measurements were made of the distribution of static pressure over the central cross section of the middle blade of each cascade, together with traverses of static pressure, total head and angle of flow at inlet and outlet to each cascade in the plane of the central cross section. The tests covered a range of actual Reynolds number from 3×10^4 to 5×10^5, based on the inlet air velocity and the blade chord, and also a range of inlet air angle α_1, from 35° to 60°. In the tests there were numerous cases of laminar boundary-layer separation at low

Reynolds numbers and a few cases of turbulent separation at higher Reynolds numbers. These occurred on the convex surfaces of the blades. There were also a few cases of laminar separation from the concave surfaces of the blades. The results show the effect of Reynolds number, blade camber, and inlet air angle on cascade performance. The type of pressure distribution likely to give good performance over a wide range of Reynolds number is discussed. From author's summary

1835. Andrews, S. J., and Ogden, H., A detailed experimental comparison of axial compressor blades designed for free vortex flow and equivalent untwisted and twisted constant section blades, *Aero. Res. Counc. Lond. Rep. Mem.* no. 2928, 20 pp., 1956.

As a contribution to the knowledge of the performance of potentially cheap compressor blades, six stages of both twisted and untwisted constant section or "strip" blades were tested at a low speed in the 106 compressor. The performance is compared with that of six stages of equivalent free vortex blades, and interstage flow traverses provide the more detailed flow information.

In terms of maximum stage efficiency, the twisted constant section blades are half a per cent better than the free vortex blades and the untwisted blades are one and a half per cent worse. Both twisted and untwisted "strip" blades have a higher surge flow than the free vortex blades, but there is very little difference in the temperature rise characteristics. At values of flow coefficient greater than the design flow, the performance of the three sets of blades becomes almost identical and the application of "strip" blades at a diameter ratio of 0.75 involves no sacrifice in performance.

Incidental tests on the relation between pressure coefficient and Reynolds number show that the maximum pressure coefficient falls to about half its original value for a change in Re from 1.3×10^5 to 0.023×10^5, and this is accompanied by a reduction in the surge point flow coefficient. From authors' summary

1836. Valdenazzi, L., On the form of a jet issuing from a swirl atomizer, *Ing. Arch.* **24,** 5, 330–340, 1956.

A rigorous treatment, with detailed derivations, of the liquid cone issuing from a swirl atomizer, and its subsequent break-up into droplets, is presented under the following assumptions: (a) the flow is continuous; (b) the liquid is inviscid; (c) the energy of flow is constant; (d) the fluid into which the jet enters does not affect the flow, and is of constant pressure; (e) the liquid motion is symmetrical about the axis. In other words, mainly the surface tension forces and the inertia forces are taken into consideration. The functions obtained are also reduced to dimensionless form. The case of very high Weber number is treated, i.e., when the surface tension forces are negligible in comparison with the inertial forces. The influence of the Weber number on the unbroken liquid surface is shown. Reference is made to the papers of Soehngen and Grigull, Doumas, and Weinberg.

K. J. DeJuhasz, Germany

1837. Fraser, R. P., and Eisenklam, P., Liquid atomisation and the drop size of sprays, *Trans. Inst. chem. Engrs.* **34,** 4, 294-319, 1956.

Paper consists of a survey of the fields of atomization and the major spraying applications of interest to the chemical engineer. It deals with drop-size determination analysis and the influence of atomizer, design, liquid property, and ambient pressure on the drop size of a spray. From authors' summary

1838. Weber, H. E., and Keenan, J. H., Head loss in flow through a cyclone dust separator or vortex chamber, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-8, 6 pp.

Paper shows by comparison with experimental results that the energy loss in a cyclone dust separator is closely approximated by a calculation with an ideal fluid except in cases where the entrance velocity is very high compared with the exit velocity. This indicates that most of the energy losses occur at the discharge end except in the case of exceedingly high velocity of rotation. H. A. Einstein, USA

Compressible Flow, Gas Dynamics

(See also Revs. 1858, 1877, 1889, 1918, 1920, 1926, 1950, 1951, 1952, 1953)

Book—1839. Oswatitsch, K., Gas dynamics. English version by G. Kuerti. (Applied mathematics and mechanics series, Vol. I), New York, Academic Press, Inc., 1956, xv + 610 pp. + 1 chart. $12.00

The striking feature of Oswatitsch's gas dynamics is the close connection between theory and physical facts. The author is never content with the mere derivation of a law, he always tries to come to grasp with the physical details, to show interrelations with other fields—sometimes of an unexpected nature—and to discuss applications. This makes for stimulating reading, even if one is familiar with the subject. A competent detailed evaluation of the book is given in the review by H. P. Liepman [AMR **6**, Rev. 2579]. The English version prepared by G. Kuerti avoids the pitfalls of a literal translation and catches the train of thought in an admirable manner. G. Guderley, USA

1840. Legendre, R., Approximative calculation of flow through a cascade of vanes (transonic) (in French), *ONERA NT* 53, 3–12, Sept./Oct. 1956.

By the use of a hodograph method author obtains an approximate shape for vanes with a prescribed velocity distribution. For exact solutions, a series development is given.

G. Temple, England

1841. Truitt, R. W., Transonic lift over the front surface of a symmetric diamond wedge, *Proc. fourth Midwestern Conf. fluid Mech.*, Purdue Univ., Sept. 1955, 245–258.

Previous paper by author [*J. aero. Sci.* **21**, Dec. 1954] is used to find the transonic chordwise lift distribution over the front surface of a symmetric diamond wedge at small angle of attack. The results are compared with existing experimental and theoretical findings. On basis of results, it is concluded that the subsonic peak in lift-slope curve is due primarily to the flow over the front wedge. From author's summary by H. Mirels, USA

1842. Keune, F., Approximation theory for the calculation of lift-free flow around slender bodies in transonic flow (in German), Jahrbuch der Wissenschaftlichen Gesellschaft für Luftfahrt, 176–186; Braunschweig, Friedr. Vieweg & Sohn, 1955.

Paper summarizes previous results by Keune and Oswatitsch, including the equivalence principle with respect to area distribution, and the method of approximating the nonlinear term of the transonic potential equation by taking $\varphi_{xx} = \text{const}$. Practically all the results have been reviewed previously [AMR **8**, Revs. 1097, 3821; **9**, Revs. 1877, 2580, 2587, 3988].

S. B. Berndt, Sweden

1843. Kuchemann, D., Methods of reducing the transonic drag of sweptback wings at zero lift, *J. roy. aero. Soc.* **61**, 553, 37–42, Jan. 1957.

Author presents a careful, lucid, nonmathematical description of the aerodynamic advantages of the swept wing and waisted fuselage. C. Ablow, USA

1844. Richards, E. J., On the noise from supersonic jets, *J. roy.*

aero. Soc. **61**, 533, 43–45, Jan. 1957.

Report describes experiments on the interaction between a shock wave and an eddy (discrete vortex) in a specially designed shock tube, and on noise measurements on convergent-divergent nozzles with cold air jets. Author concludes that such nozzles are helpful in suppressing noise, but only at a particular design Mach number. F. E. Borgnis, USA

1845. Van Dyke, M. D., The slender elliptic cone as a model for non-linear supersonic flow theory, *J. fluid Mech.* **1**, 1, 1–15, May 1956.

The second-order slender-body solution is derived for an unyawed elliptic cone in supersonic flow. Perturbation potential ϕ (which exists to second order) is determined by means of an equation whose left-hand member is $\nabla^2\phi$ in a plane normal to the axis of the cone and whose right-hand member is neglected in the first approximation, is $(M^2-1)\phi_{zz}$ in the "not-so-slender" solution, and is a more complicated expression in present work. Complete solution is sought and checked with experimental results with good agreement. It is used as a model of the full solution in order to compare more elementary theoretical results (slender-body, linearized, first- and second-order thin-wing theories; edge corrections; method of linearized characteristics).

G. Moretti, Argentina

1846. Oswatitsch, K., Calculation of vortex-free axially symmetrical supersonic fields (in German), *Öst. Ing.-Arch.* **10**, 4, 359–382, 1956.

C. Heinz and the reviewer established earlier a modified linear method of characteristics for axially symmetrical supersonic flow (see K. Oswatitsch: "Gasdynamik," Verlag Springer, Wien, 318–319, 1952), using the variables u and yv instead of u and v (u, v components of the velocity, y distance from the axis). In the present paper, Oswatitsch develops analogous nonlinear methods for transonic and for supersonic flow and obtains in this way very simple compatibility conditions. Therefore this modification of the method of characteristics is less laborious than the older methods have been. Comparison with experiments has proved that even the most simple linear method of Heinz and the reviewer gives good agreement with experiments. R. Sauer, Germany

1847. Lance, G. N., The lift of twisted and cambered wings in supersonic flow, *Aero. Quart.* **6**, 2, 149–164, May 1955.

This problem concerns the flow over a delta wing with subsonic leading edges, and the generalized conical flow theory is used to obtain an integral equation relating the velocity potential to the given downwash over the wing. The results are given in terms of tables for different downwashes up to and including homogeneous cubics in the spanwise and streamwise coordinates.

H. G. Lew, USA

1848. Roper, G. M., Some applications of the Lamé function solutions of the linearized supersonic flow equations, Part I. Finite swept-back wings with symmetrical sections and rounded leading edges; Part II. Cambered and twisted wings, *Aero. Res. Counc. Lond. Rep. Mem.* 2865, 42 pp., 1955.

Method of A. Robinson, based on separation of the linearized partial differential equation of steady flow in hyperboloido-conal coordinates, is used to determine loading on certain new supersonic wing types. Extending his own previous work [AMR **8**, Rev. 1102], author calculates zero-lift pressure distribution and drag of wings with symmetrical sections and rounded leading edges. Planforms generalize those of previous paper, having straight subsonic leading edges, parabolic trailing edges, and wing tips cut off perpendicular to root chord. Same results are also adapted to study modifications in zero-lift loading of a particular triangular wing developed by Squire, when local thickness-chord ratios are increased near the tips to improve the behavior at incidence.

Author employs lifting-type solutions from another of his papers [AMR **9**, Rev. 3997] to determine effect of Mach number changes on aerodynamic characteristics of certain cambered and twisted triangular planforms, designed to modify favorably the thrust loading on their leading edges at a given Mach number. Additional Lamé-function solutions are presented which will permit the analysis of three new classes of wings with modified leading-edge thrust.

Paper is primarily an extensive, accurate exercise in the application of a single mathematical technique. Particular wings studied show no marked theoretical advantages over others with simpler planforms and shape distributions. Certain merits suggested for them by the author might be more convincingly demonstrated by presentation of relevant experimental data, if this is available.

H. Ashley, USA

1849. Eula, A., On boundary-layer shock interference (in Italian), *Aerotecnica* **36**, 3, 177–217, June 1956.

Paper presents an extensive and careful review and analysis of the most important previously published experimental and theoretical work on the problem of boundary-layer shock interference. The systematic experimental work of Ackeret [AMR **1**, Rev. 335] and Liepmann [AMR **4**, Rev. 3609] and their collaborators is described in some detail. These results are compared with the theoretical analyses of other investigators, and it is concluded that, except for the transonic range, the present theory yields a reasonably accurate description of the physical phenomenon. A detailed presentation of the papers of Ritter and Kuo [AMR **6**, Rev. 1965] and of Crocco and Lees [AMR **6**, Rev. 1676] is presented.

P. Chiarulli, USA

1850. Boyer, D. W., Effects of kinematic viscosity and wave speed on shock wave attenuation, *Univ. Toronto Inst. Aerophys. TN* 8, 43 pp. + 25 figs. + 7 tables, May 1956.

Attenuation of shock waves traveling in tubes was investigated. Initial conditions were selected so that wave speed and kinematic viscosity behind the shock could be varied independently. The pressure ratio across the shock was found to decrease in direct proportion to both the wave speed and kinematic viscosity. The observed attenuation is compared with a theory due to Trimpi and Cohen [AMR **8**, Rev. 3508]. The agreement is fairly good when the theory is evaluated for a turbulent boundary layer behind the shock. C. F. Hansen, USA

1851. Hall, W. B., and Orme, E. M., Flow of a compressible fluid through a sudden enlargement in a pipe, *Instn. mech. Engrs. Proc.* **169**, 49, 1007–1020, 1955.

Authors develop quantitative relationships between conditions just upstream of a sudden (enlargement) discontinuity and conditions downstream. These relationships are based on conditions of continuity, momentum, and energy (adiabatic but non-isentropic) and assume that the pressure across the face of the enlargement is equal to the static pressure in the smaller tube just before enlargement. Experimental data support the theory-derived relationships. J. F. Manildi, USA

Turbulence, Boundary Layer, etc.

(See also Revs. 1849, 1890, 1918)

1852. Imai, I., Second approximation to the laminar boundary-layer flow over a flat plate, *J. aero. Sci.* **24**, 2, 155–156 (Readers' Forum), Feb. 1957.

Parabolic coordinates ξ,η are used where $Uz/\nu = \zeta^2$, $z = x + iy$, $\xi = \zeta + i\eta$; and the stream function is then assumed to be expandable in the form of a series of terms of descending order

of magnitude in ξ, for large ξ and $\eta = 0$ (1), the first term being of the form $\xi.F(\eta)$. Substitution in the Navier-Stokes equation for the stream function yields a system of equations of which the first for $F(\eta)$ is the Blasius equation. The analysis is not taken further than the next term in the stream-function series. The drag of the plate is deduced from considerations of the momentum in a large circle centered on the leading edge and is found to contain, in addition to the usual Blasius term, a term in $1/R$ and a term in $1/R^{\frac{1}{2}}$ involving an arbitrary constant. It is suggested that the latter can be obtained by linking the solution near the leading edge with that obtained by Carrier and Lin. The discussion is too summarized to invite detailed comment.

A. D. Young, England

1853. Meksyn, D., Integration of the boundary-layer equations, *Proc. roy. Soc. Lond.* (A) **237,** 1211, 543-559, Nov. 1956.

A method of integration of the boundary-layer equations previously described by the author [AMR **1**, Rev. 1144; **4**, Rev. 816] is improved in the present paper. As a check, the new procedure is applied to the Falkner-Skan equation and, with comparatively little effort, close agreement is obtained with Hartree's numerical results.

The method is also applied to the general boundary-layer equations for the case of incompressible flow past an elliptic cylinder, where Shubauer's observed pressure distribution is assumed to hold outside the boundary layer. The position of the separation point is obtained by approaching it from downstream, a procedure justified by the author in the present problem on the grounds that the separation point is not a singularity. The procedure cannot be applied for inviscid flow pressure distribution outside the cylinder or for retarded flow past a semi-infinite plate.

A. R. Mitchell, Scotland

1854. Hansen, A. G., and Herzig, H. Z., Analysis of particle motions for a class of three-dimensional incompressible laminar boundary layers, *NACA TN* 3840, 21 pp., Nov. 1956.

Problem treated is that of determining the positions of particles at any given time in a three-dimensional incompressible laminar boundary layer on a flat surface for two-dimensional main flows whose axial (chordwise) velocity component is constant and whose spanwise component can be represented by polynomials in the axial coordinate.

It is found that boundary-layer particles initially aligned on a normal to the surface trace out twisted surfaces as they move downstream. Tables are presented for the computation of particle paths for main-flow streamlines approximated by third-degree polynomials. The tables also facilitate calculations of the time interval that a particle remains near the bounding surface for a given configuration.

S. Ostrach, USA

1855. Berlyand, O. S., On the approximate solution of certain problems in the hydrodynamics of the boundary layer (in Russian), *Trudi Geofiz. in-ta Akad. Nauk SSSR* **no. 22, 127-130, 1954; Rev.** no. 945, *Ref. Zh. Mekh.* 1956.

Author examines the familiar problem of wind distribution in height in a turbulent atmosphere, on the assumption that the coefficient of turbulent mixing is a linear function of the altitude, whereas the pressure gradient is independent thereof.

An approximate solution is sought, by a method suggested by M. E. Shvets [*Prikl. Mat. Mekh.* **13,** 3, 1949].

Courtesy of Referativnyi Zhurnal E. M. Dobryshman, USSR
Translation, courtesy Ministry of Supply, England

1856. Sukharevsky, I. V., On a boundary problem of hydrodynamics (in Russian), *Dopovidi Akad. Nauk SSSR* no. 1, 39-42, 1955; Rev. no. 801, *Ref. Zh. Mekh.* 1956.

Proof is given of a theorem relating to the construction of the continuous solution $u(s)$ of the integral equation associated with the boundary problem of the determination of the velocity of a two-dimensional flow of an ideal incompressible fluid, for the case of a continuous flow around a simple, partially-smooth profile C ($z = z(s)$; $-l_2 \leqslant s \leqslant l_1$) with a single angular point $z_0 = z(0)$ in the presence of a discrete or continuous distribution of singularities in the flow region

$$u(s) - \frac{1}{\pi} \int_C u(\sigma) \frac{\partial \ln|\zeta - z|}{\partial n_s} d\sigma = 2Re[w_0(z)z'(s)]$$

($w_0(z)$ = complex velocity of the undisturbed flow, $\zeta = z(\sigma)$, n locus of the external normal).

Let $\arg z'(s)$ satisfy the Lipschitz condition with a positive exponent, in the intervals $[-l_2, 0]$, $[0, l_1]$; and let C' be an arc of the convex profile C, on which

$$\epsilon_1 \leqslant s \leqslant l_1 \quad -\epsilon_2 \geqslant s \geqslant -l_2$$

$$K(\sigma,s) = \frac{1}{\pi} \frac{\partial}{\partial n_s} \ln|\zeta - z|$$

(n locus of the internal normal). Then

(1) The integral equation

$$u_\lambda(s) - \lambda \int_{C'} K(\sigma,s)\, u_\lambda(\sigma) d\sigma = 0$$

has no characteristic values in the circle $|\lambda| \leqslant |$, and consequently, the equation

$$u_1(s) - \int K(\sigma, s)\, u_1(\sigma) d\sigma = f(s)$$

with a continuous right-hand half on C', has a single continuous solution $u_1(s)$;

(2) If $f(s)$ is intermittently continuous along C with a single possible point of discontinuity z_0 and the integral equation

$$u(s) - \int_C K(\sigma,s)\, u(\sigma) d\sigma = f(s)$$

has a continuous solution $u(s)$ equaling zero at the angular point, then

$$u_1 \longrightarrow u \left(\text{for } \epsilon_1 \longrightarrow 0, \quad \epsilon_2 \longrightarrow 0, \quad \frac{\epsilon_2}{\epsilon_1} = 0(1) \right)$$

is regular along any arc of the profile C not containing an angular point

Yu. D. Sokolov, USSR
Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1857. Tsuji, H., Experimental studies on the spectrum of isotropic turbulence behind two grids, *J. phys. Soc. Japan* **11,** 10, 1096-1104, Oct. 1956.

Measurements were made of the longitudinal component of turbulence behind two grids of 5-cm and 1-cm mesh (the larger mesh grid is upstream) for various grid spacings at wind speeds up to 15 mps. Similarity of the energy spectrum is limited to large wave numbers, whereas the vorticity spectrum shows similarity over the entire wave number range. The turbulence superposed by the second grid is in the high wave number range but decay is rapid enough so that, for distances equal to or greater than 20 mesh lengths, similarity of the energy spectrum again obtains in the high wave number range.

A. M. Kuethe, USA

Aerodynamics of Flight; Wind Forces

(See also Revs. 1683, 1847, 1848, 1895, 1937, 1966)

1858. Leslie, D. C. M., An introduction to second-order wing theory, *J. aero. Sci.* **24,** 2, 99–106, Feb. 1957.

The particular integral for the second-order iteration equation of inviscid supersonic flow, discovered by Fell and the author, is applied to wing theory. This enables author to calculate second-order derivatives for wings of finite aspect ratio, and thence to determine how far the second-order strip theory of Busemann is in error for such wings. Remarking that the most interesting effect in second-order wing theory is the influence of thickness on lifting derivatives, and that corrections to strip theory will be largest on a wing with subsonic edges, author chooses as an example the lift coefficient of a rectangular wing with a simple thickness distribution.

Some details are given of the calculation, which is fairly complex; use of the ζ method introduced by Perry and the author is found to reduce the labor involved very considerably.

From author's summary by H. P. Eichenberger, USA

1859. Gambucci, B. J., Section characteristics of the NACA 0006 airfoil with leading-edge and trailing-edge flaps, *NACA TN* 3797, 17 pp., Dec. 1956.

1860. Legendre, R., Vortex formation at the leading edge of an airfoil (in French), *C. R. Acad. Sci. Paris* **243,** 12, 838–840, Sept. 1956.

Outline of inviscid theory of two-dimensional airfoil flow with reattachment behind sharp leading edge. The theory is based on the assumption of constant vorticity in the region between airfoil and separated flow. Argument given for this hypothesis is stated very briefly and, to the reviewer, not quite convincingly.

L. J. F. Broer, Holland

1861. Wurster, H., Neutral point of an airplane (in German), Jahrbuch der Wissenschaftlichen Gesellschaft für Luftfahrt, 161–167; Braunschweig, Friedr. Vieweg & Sohn, 1955.

Paper describes method of predicting the (stick-fixed) neutral point of an airplane from preliminary design data. Agreement of theory with flight test on Messerschmidt airplanes (around 1940 vintage) was excellent. Method consists of determining the neutral point of the airplane as the centroid of the individual neutral points for the wing, the horizontal tail, and the propeller. The destabilizing effects of fuselage and nacelles are included as correction terms, and the effects of subsonic compressibility are discussed briefly.

H. P. Liepman, USA

1862. Foster, G. V., and Griner, R. F., A study of several factors affecting the stability contributed by a horizontal tail at various vertical positions on a sweptback-wing airplane model, *NACA TN* 3848, 28 pp., Nov. 1956.

A study was made in the Langley 19-ft pressure tunnel to determine the effects of fuselage afterbody shape, split flaps, and variations in the span of the leading-edge flaps on the stability contributed by the horizontal tail to an airplane with the wing leading edge swept back 42°. Supplementary tests were made to determine some of the characteristics of the air flow in the vicinity of the tail, the wing being equipped with 0.575-span leading-edge flaps and 0.5-span split flaps. All data were obtained at a Reynolds number of 6.8×10^6.

From authors' summary

1863. Kirby, R. H., Flight investigation of the stability and control characteristics of a vertically rising airplane research model with swept or unswept wings and ×- or +- tails, *NACA TN* 3812, 30 pp., Oct. 1956.

Paper presents the results of an investigation of the dynamic stability and controllability of a propeller-driven vertically rising airplane model which had swept or unswept wings and cruciform tails with ×- or +-orientation. The investigation consisted of hovering flights in still air at a considerable height above the ground, hovering flights very close to the ground, vertical take-offs and landings, flights through the transition range from hovering to normal forward flight, and sideways translational flights. It was found that there were no major differences in the behavior of any of the model configurations, and in general they could all be flown fairly easily in either hovering or transition flight.

From author's summary

1864. Oswald W. B., Applied aerodynamics and flight mechanics, *J. aero. Sci.* **23,** 5, 469–484, May 1956.

1865. Dickinson, R. P., Assessment of the aircraft for its part in a defence system, *AGARD Rep.* 32, 8 pp., Feb. 1956.

1866. McArdle, J. G., Performance characteristics of ring-cascade-type thrust reversers, *NACA TN* 3838, 53 pp., Nov. 1956.

1867. Tapscott, R. J., and Amer, K. B., Studies of the speed stability of a tandem helicopter in forward flight, *NACA Rep.* 1260, 12 pp., 1956.

Flight test measurements, related analytical studies, and corresponding pilots' opinions are presented. An undesirable instability is indicated to be caused by variations with speed of front-rotor downwash at rear rotor. An analytical expression for predicting changes in speed stability caused by changes in rotor geometry is derived. Means for improving stability with speed are studied both analytically and experimentally.

From authors' summary by G. Isakson, USA

1868. Gelder, T. F., Smyers, W. H., Jr., and von Glahn, U., Experimental droplet impingement on several two-dimensional airfoils with thickness ratios of 6 to 16 percent, *NACA TN* 3839, 77 pp., Dec. 1956.

Propellers, Fans, Turbines, Pumps, etc.

(See also Revs. 1697, 1746, 1834, 1835, 1896, 1910)

1869. Scholz, N., On the arrangements for systematic measurements in two-dimensional cascades (in German), *Z. Flugwiss.* **4,** 10, 313–333, Oct. 1956.

Experimental techniques for study of flow through cascades are discussed with emphasis on requirements for design of cascade wind tunnels. Description is given of tunnel developed by author and constructed at Institute for Fluid Mechanics at the Technical University of Braunschweig.

In a discussion of analysis of flow measurements, author derives equation of momentum for two-dimensional flow through cascades. A simple method of solving wake flow is derived. Another scheme for converting measured values to two-dimensional values is presented. This corrects for the presence of the boundary layers on sides of tunnel. Further discussion is given on evaluation of pressure-distribution measurements and presentation of results in nondimensional quantities.

Final part of paper is results obtained from cascades with symmetrical airfoil sections of N.A.C.A. 0010 shape. Methods derived in paper are used for evaluation.

From author's summary by W. D. Baines, Canada

1870. Novikova, O. I., Selection of the optimum velocity diagram for compressor cascades (in Russian), *Teploenergetika* **3,** 3, 30-33, Mar. 1956.

1871. Kromov, A. G., Investigation of the flow in the wake behind a cascade of moving blades (in Russian), *Sb. Nauk Trudî Ivanovsk. Energ. Inst.* no. 6, 81-85, 1955; Rev. no. 139, *Ref. Zh. Mekh.* 1956.

The problem is examined of the levelling of the flow of a cascade of blades, and the energy losses are determined in the mixing of the flow right up to complete levelling. Starting from the assumption that, in the absence of external forces, the sum of the pulses of forces of pressure and the quantity of motion for all control sections behind the cascade, identically orientated with reference to it, remains constant, and that the mean density in the wake does not vary, author derives equations for the nondiscontinuity, the quantity of motion and energy, for two sections behind the cascade. The calculated data are compared with the results of the experiments made with a cascade of moving blades at a flow velocity of 50 m/s. The chord of the blades is 50 mm, the pitch 34.5 mm, the thickness of the trailing edge 35 mm. Relatively large losses in levelling in author's experiments are connected with the fact that the cascade tested had low efficiency and a relatively thick edge. Author suggests determining the aerodynamic properties of the cascade in the flow conditions at infinity behind the cascade, (taking into account the loss in levelling) effecting conversion according to the formulas which he has given.

It is pointed out that the notation does not correspond to the graphs in Fig. 1. A. I. Bunimovich, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1872. Shubovich, S. I., Experimental investigation of the frictional and flow losses in a turbine stage (the calculation and design of a reversible pneumatic turbine) (in Russian), *Izer. Tomskogo Politek. Inst.* **75,** 310-330, 1954; Rev. no. 140, *Ref. Zh. Mekh.* 1956.

Results are given of an experimental investigation of the friction and flow losses in a small power pneumatic turbine. On the basis of the experimental investigations made, a numerical calculation of the coefficients of a pneumatic turbine is given, provided with a reversing stage. I. E. Idel'chik, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1873. Bogdanova, V. V., and Belova, N. T., The flow near a working rotor of a hydrotubine (in Russian), *Trudî Leningr. Politek. Inst.* no. 176, 61-75, 1955; Rev. no. 212, *Ref. Zh. Mekh.* 1956.

An experimental investigation was made of the space field of velocities of an air flow through the working rotor of a model of a hydroturbine. Measurements were made with a spherical probe moving along a radius, several sections in front of the working rotor and behind it. Comparison was made of the pressures measured on rotating blades and calculated (by the EGDA method) on the profile of the corresponding plane cascade. The efficiency of the working rotor is calculated according to the torque on the turbine shaft, which is measured directly and calculated from Euler's formula (as the difference of the mean torques of a number of motions in front of the working rotor and behind it). The mean values of the measured parameters (along one radius) of the flow were calculated approximately as the mean according to the area.

Considerable difference was noted in the values of the efficiency calculated from the measured results of the parameters in different sections. This difference, which amounts to 20%, indicates the inaccuracy of the experiment, since, with correct measurements and correct handling, the torque on the turbine shaft, and the efficiency of the working rotor, respectively, ought not to depend upon the choice of the measuring section (with an accuracy up to the frictional torque disregarded in the calculations, of the liquid against the turbine casing). There is also an assertion (p. 61) which does not correspond to reality, that theoretical methods of investigating the flow of a fluid through a working rotor are based on the correctness of the hypothesis of the cylindrical sections. G. Yu. Stepanov, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1874. Tyryshkin, V. G., On choosing the method of designing the blade length of turbine stages (in Russian), *Izv. Akad. Nauk SSSR, Otd. tekh. Nauk* no. 6, 37-44, 1954 (translated from Russian by M. D. Friedman, 572 California St., Newtonville, Mass., 13 pp.)

At the present time, a number of so-called "aerodynamic" methods are known which permit taking into account the actual distribution of the flow parameters in separate characteristic sections of gas-turbine stages (in front of the guide vanes, in the gap between the guiding and operating vanes, and outside the operating wheel) and, therefore, estimating the efficiency of the blades.

Characteristic of these methods is the use, in deriving computational formulas, of the equations of continuity and energy for a stream tube element and also the equilibrium condition of an elementary volume of gas in the radial direction. Here, the motion of the working fluid is assumed steady and axisymmetric relative to the control sections listed above.

From author's summary

1875. Ashwood, P. F., A review of the performance of exhaust systems for gas-turbine aero-engines, Instn. mech. Engrs., Prepr., 18 pp.

1876. Sherstiuk, A. N., Determination of the stability limits of fans, pumps, and compressors (in Russian), *Inzbener. Shornik, Akad. Nauk SSSR* **21,** 195-202, 1955.

In his investigation of pumping limits, author has considered the combined operating characteristics brought about by the interaction of both pump, blower, or compressor, and associated equipment and ducting of certain particular installations which are of practical interest.

For blowers, as is usual, variations of density of air are disregarded in the analysis of pressure oscillations. In the results, presented in tabular form, regions of critical stability for several typical configurations are defined.

For compressors, both centrifugal and axial flow, density variations are accounted for in the equation for pressure fluctuations. After linearization of this equation, achieved by disregarding deviations due to pulsations from the steady compressor characteristic, an expression is given in terms of the Mach number of flow in the system for the limiting pressure pulse permissible for steady operation. Its magnitude is indicated by treating a particular example. J. R. Weske, USA

1877. Zucrow, M. J., The problems of the turbojet engine as a propulsion engine for supersonic flight, *Aero. Engng. Rev.* **15,** 12, 44-51, 61, Dec. 1956.

General discussion of performance is presented in terms of three parameters: (a) Specific engine weight; (b) thrust per unit of frontal area; (c) thrust specific fuel consumption. Turbojet engines for supersonic flight will require (1) variable inlet area diffusers, (2) high pressure ratio and large induction-capacity air compressors, (3) turbines operating at high inlet temperatures, (4) combustion systems operating at high inlet air velocities and low inlet air pressures, and (5) variable area converging-diverging exhaust nozzles. A. Petroff, USA

1878. Ainley, D. G., The high temperature turbo-jet engine, *J. roy. aero. Soc.* **60,** 549, 563–589, Sept. 1956.

1879. Roberts, H., Aerodynamic aspects of helicopter design, *J. Helicop. Assn.* **10,** 1, 24–70, July 1956.

Flow and Flight Test Techniques

(See also Rev. 1869)

1880. Wick, R. S., Some aspects of the measurement of oscillatory hydraulic flow including nonlinear effects, *Jet Propulsion* **26,** 12, 1078–1083, Dec. 1956.

An analytical exercise of only academic interest since, besides a number of simplifying assumptions such as incompressibility, unidimensionality, as well as some geometrical simplifications, the problem treated concerns the unrealistic effect of a postulated sinusoidal variation in pressure differential on flow rate, rather than the "natural" effect of pulsating flow on the measurement.

A. K. Oppenheim, USA

1881. Newell, F. B., Diaphragm characteristics, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-220, 22 pp. + 36 figs.

The characteristics of diaphragms determined by tests are described in a systematic arrangement. The effects of pressure, force and deflection on the force constant, pressure constant, effective area and available energy are illustrated by graphs.

From author's summary

1882. Lyon, F. H., and Grover, H. J., Some suggestions for research in diaphragm technology, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-221, 9 pp. + 3 figs.

1883. Nesbitt, M. V., Correcting orifice meters for pulsating flow—significance of wave form and acoustic effects, *Engineering* **182,** 4716, 108–110, July 1956.

1884. Boros, J., Measurement of flow velocities by thermosensitive metallic oxides (thermistors) (in Hungarian), *J. Hydrology* **36,** 3, 166–170, June 1956.

According to the method suggested for measuring flow velocities, electric current is passed through a coil for a short period, thus transmitting heat to the water. Recording thermocells are used to intercept the heated water, and the change in resistance caused thereby is indicated by the current meter of a Wheatstone bridge. Using two thermocells, the velocity of flow can be determined by measuring the time difference between signals received, and the distance of the two cells. Control measurements were carried out using gas pipes of two different diameters and a pipe having a diameter of 100 mm. In the case of gas pipes, the discharged volume was determined to control flow velocities measured by the thermocell method, whereas, in the latter case, a measuring weir was used for the same purpose. These tests show the suggested method to be highly accurate, deviations obtained being but 1% or less for velocities ranging in order of magnitude from a mere few centimeters per second up to meters per second.

From author's summary by T. P. Torda, USA

1885. Lee, J. C., and Ash, J. E., A three-dimensional spherical pitot probe, *Trans. ASME* **78,** 3, 603–608, Apr. 1956.

The mechanical alignment of a conventional 5-hole probe to balance the readings of the opposite holes in both planes or only in one plane may be avoided by three-dimensional calibration of the instrument. Authors propose to use as inclination factors the ratios $(k_1 - k_3)/(k_0 - k_3)$ and $(k_2 - k_4)/(k_0 - k_3)$, both being functions of the angles of pitch and yaw and assumed independent of Reynolds number in a limited range. Subscript 0 refers to the center hole. Opposite holes in the one plane bear the subscripts 2 and 4, and the holes in the other plane 1 and 3.

Calibration curves for a 0.19-in. probe are compared with the curves from potential-flow theory assuming no effect of the support stem. Minor deviation from theory is attributed to center-hole misalignment. Three per cent accuracy is claimed for velocity and static pressure.

Apart from the two major questions discussed briefly as to the change of calibration with large velocity gradients and the stream Mach number, reviewer would welcome a comparison, drawn from authors' data, between proposed method and that of G. Jegorow who suggested for calibration factors the ratios $(k_0 - k_1)/(k_0 - k_3)$ and $(k_0 - k_2)/(k_0 - k_4)$ [*Luftfahrtforschung* **19,** p. 326, 1942].

Y. K. Jan, Holland

1886. Coleman, M. C., Variable area flow meters, *Trans. Inst. chem. Engrs.* **34,** 4, 339–350, 1956.

Paper discusses the theory of a variable area flowmeter and shows how compensation for changes in density of the fluid being metered can be obtained by making the float density twice the mean fluid density. It is shown how float shape influences both the flow coefficient and the effect of viscosity.

A method is explained which enables the combination of tube and float in a variable area flowmeter to be predicted for almost all applications without the need for flow testing.

Consideration is given to some industrial variable area flowmeters and it is shown how certain of these instruments can be used for automatic flow and flow ratio control. It is also shown how a variable area flowmeter can be used as a "kinetic monameter" to measure flow rate.

From author's summary

1887. Suleimanova, R. Z., Capillary closed viscometer (in Russian), *Zh. Fiz. Khim.* **28,** 10, 1820–1824, 1954; Rev. no. 339, *Ref. Zh. Mekh.* 1956.

A viscometer is described which represents a closed capillary, in which the viscosity of the liquid is determined by the time of its flow along a known distance if the constant parameters of the instrument are known. A liquid in the instrument is insulated from the external medium. The determination of the viscosity is possible in it at temperatures both below and above the B. P. of the liquid investigated. A method is described of determining viscosity with this instrument in various conditions, and the results are given for seven different liquids, which were in good agreement with data from other sources.

S. G. Popov, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1888. Sherman, Pauline M., Visualization of low-density flows by means of oxygen absorption of ultraviolet radiation, *J. aero. Sci.* **24,** 2, 93–98, 106, Feb. 1957.

Paper investigates possibilities for quantitative measurement of density field. Experimental conditions were 2-in. diam. jet, $M \sim 3.9$, static pressure ~114μHg. Source was xenon discharge lamp with vacuum spectrograph-monochromator to isolate the resonance radiation at 1470 A; optical system was of calcium fluoride. Exposure times were 50 to 90 sec.

Analysis was handicapped by limited emulsion response data. Paper examines physical limitations of method and lists further investigations needed before it can become a practical tool.

R. C. Pankhurst, England

1889. Dubois, G., Method of visualization of supersonic flow (in French), *ONERA* no. 53, 33–42, Sept./Oct. 1956.

Paper describes a method of two-dimensional flow visualization

in a supersonic wind tunnel by means of Mach waves and wakes, observed with a schlieren system and produced by a series of thin nylon threads stretched across the working section upstream of the model. The effect of thread diameter was investigated and 0.001-in. diam size was used. The method did not lend itself to three-dimensional flow visualization. J. Lukasiewicz, Canada

1890. Bazzocchi, E., Boundary-layer flow-visualisation tests in a low velocity wind tunnel (in Italian), *Aerotecnica* **36**, 5, 315–332, Oct. 1956.

The visualization of flow in the boundary layer can give very useful indications on the running of the complicated phenomena which rule the aerodynamic characteristics of wings. The writer illustrates a set of experiences carried out in the wind tunnel on a swept wing and the correspondent unswept one by using, for the visualization, a mixture of kerosene and carbon-black. In addition, relations are evidenced between the aspects and modifications of flow in the boundary layer and the running of forces and moments on the two different types of wing.

From author's summary

1891. Dunne, B. B., and Cassen, B., Behaviour of shock waves entering model basis bomb shelters, *Proc. Amer. Soc. civ. Engrs.* **82**, ST 2 (*J. Struct. Div.*), Pap. 919, 7 pp., Mar. 1956.

The use of a spark shadowgraph with effective exposure time of a fraction of a microsecond has enabled very sharp pictures to be obtained of the time sequence of shock-wave advance, reflection, diffraction, and turbulent breakup in models placed in a 4 × 4-in. square cross-section shock tube. The equipment has been used to gain considerable information on the penetration of shock waves into model shelters. Although it is expected that inertial forces would scale accurately in small models, it is evident from the results that viscous forces play an important part in kinetic energy dissipation, and these forces would not be expected to scale accurately. However, the production and behavior of strong vortexes in the models indicate that they should be considered as a full-scale factor in effects on personnel.

From authors' summary

1892. Wiggins, J. W., Kuhn, R. E., and Foumier, P. G., Wind-tunnel investigation to determine the horizontal- and vertical-tail contributions to the static lateral stability characteristics of a complete-model swept-wing configuration at high subsonic speeds, *NACA TN* 3818, 34 pp., Nov. 1956.

An investigation was conducted in the Langley high-speed 7-by 10-ft tunnel to determine the horizontal- and vertical-tail contributions to the static lateral stability of a complete-model swept-wing configuration at high subsonic speeds. The results indicate that, in general, Mach number effects within the range studied and wing effects on the tail contribution were small and the over-all trends of the data of the present investigation agreed with those which have been established at low speeds. The contribution of the vertical tail to the directional stability C_{n_β} at zero angle of attack increases slightly with Mach number and can be adequately predicted when the load is assumed to act at the aerodynamic center of the vertical tail $\bar{c}_V/4$ and when the end-plate effect of the fuselage on the theoretical lift-curve slope of the tail is considered. The vertical tail contributes a stabilizing increment to the directional stability C_{n_β} at all angles of attack; however, at the higher angles of attack the tail contribution is greatly reduced. The vertical-tail contribution to the effective-dihedral derivative C_{l_β} at zero angle of attack increases slightly with Mach number and can be estimated satisfactorily when the geometric center of load $\bar{c}_V/4$ and the end-plate effect of the fuselage on the theoretical lift-curve slope of the tail are considered. The rate of change of the effective-dihedral derivative with angle of attack $\partial(C_{l_\beta})_V/\partial\alpha$ was greater throughout the Mach number range than calculations indicated. The end-plate effect of the fuselage on the vertical tail decreased with Mach number and indicated good agreement with low-speed data at the lowest Mach number. Interference effects of the wing and horizontal tail on the lateral-stability derivatives were small at the lower angles of attack.

From authors' summary

1893. Eckhaus, W., The theoretical background of the design of a transonic test section (in Dutch), *Ingenieur* **68**, 3, 11–16, Jan. 1956.

1894. Brebner, G. G., and Bagley, J. A., Pressure and boundary-layer measurements on a two-dimensional wing at low speed, *Aero. Res. Counc. Lond. Rep. Mem.* 2886, 47 pp., 1956.

Results are given of pressure measurements and boundary-layer traverses on a two-dimensional wing with 10% RAE 101 section at Reynolds numbers of 1.6×10^6 and 3.2×10^6. These results, which have been integrated to give lift, drag, and aerodynamic-center characteristics, are used to check some calculation methods for the growth of the turbulent boundary layer and for the effect of a known boundary layer on the pressure distribution.

It is concluded that the calculation of the boundary layer still needs a little refinement before it is accurate enough to predict viscosity effects on pressure distribution, lift, drag, and aerodynamic center; but that these effects can be calculated if the actual boundary-layer characteristics are known.

From authors' summary

1895. Black, J., An experimental investigation of the effects of deformation on the aerodynamic characteristics of a swept-back wing, *Aero. Res. Counc. Lond. Rep. Mem.* 2938, 34 pp., 1956.

A wind-tunnel investigation of the effects of structural deformation on the pressure distributions round a tapered wing, with 44-deg leading-edge sweepback, has been carried out over a range of deformations at a Reynolds number of 0.6×10^6.

A technique for constructing a model and deforming it into any desired deformation has been successfully developed. The model is made of Perspex which becomes plastic at 100 C; after being boiled in a water bath the model can be deformed into any desired deformation and, on cooling, it sets hard with the deformation "frozen" in. When the model is boiled again it reverts to its undeformed shape and a new deformation can then be applied while it is in its plastic state. The cycle can be repeated any number of times with the same model, to cover a range of deformations.

From the modes investigated the appropriate deformations required to produce an almost elliptic span loading at a selected moderate over-all lift, or to delay tip stalling at high incidence, were established. The most important feature is to have a maximum wash-out at about 0.7 semi-span, with a decrease of washout from there to the tip, and not a continuously increasing washout right to the tip.

The Weissinger method for theoretical prediction of airloads was found to be reasonably satisfactory for the effect of deformation at low incidence. From author's summary

1896. Priadilov, A. I., Experimental investigation of surging in a stage of an axial compressor with 100% reaction (in Russian), *Teploenergetika* **3**, 1, 49–52, Jan. 1956.

1897. Maimoni, A., Hot wire liquid-level indicator, *Rev. sci. Instrum.* **27**, 12, 1024–1027, Dec. 1956.

The theory of the method of measurement of liquid level by measurement of the resistance of a heated wire is developed, and it is applied to the design of a liquid-nitrogen-level indicator. This indicator was a platinum ribbon 0.001 × 0.0002-in., having a power dissipation of 3.4 mw/in. of length and a deviation from linearity in the calibration of less than 0.1 in. over its working

length of 2.01 n. The sensitivity of the apparatus is limited only by the temperature coefficient of resistance of the heated wire.

From author's summary by C. Codegone, Italy

Thermodynamics

(See also Revs. 1735, 1874, 1875, 1878, 1885, 1915, 1917, 1950, 1951, 1952, 1953, 1957, 1960, 1984)

Book—1898. Schmidt, E., Introduction to technical thermodynamics and to the fundamentals of chemical thermodynamics [Einführung in die technische Thermodynamik und in die Grundlagen der chemischen Thermodynamik], 6th ed., Berlin, Springer-Verlag, 1956, xvi + 522 pp. + 1 table. DM 30.

This book is the sixth enlarged edition, the fifth of which was reviewed in AMR **7**, Rev. 4049. According to author's preface, certain changes have been incorporated into this edition. According to international agreement, the Thermodynamic Temperature Scale is defined with a new triple point and freezing point of the water. The MKSA system is thoroughly discussed. The tables with properties of steam were expanded up to 800 C.

From author's preface by editor

1899. Landsberg, P. T., Foundations of thermodynamics, *Rev. mod. Phys.* **28,** 4, 363–392, Oct. 1956.

1900. Ritland, H. N., Limitations of the fictive temperature concept, *J. Amer. ceram. Soc.* **39,** 12, 403–406, Dec. 1956.

The fictive temperature formalism, in which the structural state of the glass is characterized by the fictive temperature r, is very useful in the qualitative description of the effects of thermal treatment in the transformation range. Experimental data are presented which show, however, that such a one-parameter description has only a limited quantitative significance. When samples of a borosilicate crown glass, annealed at various constant cooling rates, are compared with samples annealed at constant temperature, it is found that a single parameter does not specify all physical properties simultaneously and that the two types of samples differ markedly in transformation-range kinetic phenomena. Properties studied include density, refractive index, low-temperature thermal expansion, approach to equilibrium at constant temperature, and thermal expansion during heating in the transformation range.

From author's summary

1901. Nomoto, O., Irreversible production of entropy and the absorption of sound, *J. phys. Soc. Japan* **11,** 8, 818–826, Aug. 1956.

Author has calculated sound absorption coefficient from the irreversible production of entropy due to heat conduction between the external and internal degrees of freedom of the molecules. It is another attempt toward the derivation of the absorption based on irreversible thermodynamics similar to that of Herzfeld and Rice and others. Final formula is the same as that of Kneser for absorption in gases.

G. Verma, India

1902. Meijer, P. H. E., Extension of the statistical proof of the minimum entropy production theorem, *Phys. Rev.* (2) **103,** 4, 839–844, Aug. 1956.

Proof of minimum entropy production in the steady state is extended to systems obeying Fermi-Dirac or Base-Einstein statistics. The proof requires the assumption of microscopic reversibility. The paper further extends the proof for the case of a variable number of particles, as exemplified by a thermal diffusion process.

M. A. Biot, USA

1903. Hirschfelder, J. O., Buehler, R. J., McGee, H. A., Jr., and Sutton, J. R., Generalized thermodynamical excess functions for gases and liquids, II, *Univ. Wisc., Nav. Res. Lab., Dept. Chem. Tech. Rep.* WIS-OOR-16, 19 pp., Nov. 1956.

Concise formulas are derived for the thermodynamical excess functions of gases and liquids on the basis of generalized corresponding-states equation of state given. These relations, together with the pressure as a function of density and temperature, are given in a form suitable for high-speed digital computations.

Figures are given for the variation of the principal thermodynamical excess functions with density for nitrogen at four different temperatures.

From authors' summary

1904. Kirillin, V. A., Sheindlin, A. E., and Shpil'rain, E. E., New tables of reference values of specific volume, specific heat and enthalpy of water and water vapor at elevated pressures and temperatures (in Russian), *Teploenergetika* **3,** 1, 16–21, Jan. 1956.

The existing values of specific volume, specific heat, and enthalpy for water and water vapor, adopted in 1934 by the International Conference on Steam Tables, cover thermodynamic properties only up to 300 atm at 550 C which, according to authors, were arrived at by extrapolation, rather than being based on actual experimental data.

To present more accurate values of thermodynamic properties at much higher pressures, the authors make a comparative analysis of existing experimental data of their co-workers in Russia, and Case and Kennedy in U. S. A.

On the basis of this analysis they worked out three reference tables; one for specific volume, one for specific heat, and one for enthalpy at pressures of 500 atm (abs) and 550 C.

W. Green, USA

1905. Hohl, R., New steam tables (in German), *Schweiz. Bauztg.* **74,** 42, 641–647, Oct. 1956.

A brief review is made of several new steam tables, including comparison with the well-known work in the United States of Keenan and Keyes in 1936, the VDI by Koch in Germany in 1937, Calendar in 1939, and Sugawara in Japan in 1950. These tables were all compared among themselves with the work of Dr. Koch as a reference. The agreement among the several tables was ± 1 kilogram calorie per kilogram in enthalpy. The deviations of the earlier tabulations from the Brown, Boveri & Co. tables are larger, amounting to as much as 3 kilogram calories per kilogram at 100 atm and in one or two instances as much as 6 kilogram calories per kilogram at 300 atm. Comparisons are presented in graphical and tabular form.

B. H. Sage, USA

1906. Giulianini, A., The equilibrium constant of a mixture of real gases (in Italian), *Termotecnica* **10,** 8, 333–337, Aug. 1956.

Expressing the thermodynamic potential of a homogeneous mixture of real gases as a function of their virial coefficients, a new equation is derived which allows the calculation of the equilibrium constant of the mixture from experimental thermodynamic data of the components. The old and the new expression for the equilibrium constant hold only if it is assumed that the volume of the mixture is equal to the sum of the partial volumes of single components. Equilibrium constants for two gas mixtures are calculated according to both methods and it is shown that the differences are small.

From author's summary by A. Kuhelj, Yugoslavia

1907. Tang, W. K., Properties of gaseous and liquid mixtures, *Univ. Wisc., Nav. Res. Lab., Dept. Chem. Tech. Rep.* WIS-OOR-13, 199 pp., Aug. 1956.

These assembled tables of p–v–t data of gaseous and liquid mixtures were collected from the published literature (1933–1954)

for 41 binary and 2 ternary systems, representing 14,000 points from 218 different compositions and 23 compounds. The purpose of this assemblage is to make such data readily available for establishing subsequently the pseudo-reduced properties and generalized correlations of mixtures.

From author's summary

1908. Johnson, A. I., and Furter, W. F., Algebraic representation of vapor-liquid equilibrium data, *Canad. J. Technol.* **34,** 7, 429-441, Jan. 1957.

The relative merits of algebraic versus thermodynamic correlations of nonideal vapor-liquid binary equilibrium data are discussed. A survey of previous attempts at algebraic representation is given. A rapid and easily handled algebraic representation is proposed that meets the criteria for such expressions, containing only two empirical constants both readily evaluated from a simple straight-line plot, relating x and y directly, and permitting the calculation of azeotropic compositions. Its merit lies in its simplicity.

The equation was subjected to a critical test with 57 different binary systems. It was found to represent, in general, systems containing no strongly polar or long-chained components and, in the more limited case, systems in which both components are polar but are of somewhat similar molecular types and sizes, and degrees and types of polarity. The accuracy was better than one per cent over the ranges for which data were available. For these types of systems, the equation is concluded to be useful from a practical standpoint for engineering calculations such as the calculation of azeotrope compositions, and for representing experimental, nonideal vapor-liquid equilibrium data within the described limitations.

From authors' summary

1909. Kalafati, D. D., Thermodynamic analysis of reheat cycles in steam-turbine installations (in Russian), *Teploenergetika* **3,** 3, 39-47, Mar. 1956.

An analytical expression for thermal efficiency of reheat-regenerative cycle of a steam turbine is derived. Parameters are steam state in low- and high-pressure stages of the turbine, thermal efficiencies of both stages, energy used in feedwater pumps, thermal loss in heat exchangers, and pressure drop in reheaters.

Author underlines that to achieve maximum thermal efficiency of reheat-regenerative cycle it is necessary to complete the regeneration and reheating under optimum conditions. Therefore, he initially assumes the parameters of reheating process to be predetermined, and ascertains the optimum starting temperature of regeneration in low-pressure stage, which, for this case, results in the cycle with maximum thermal efficiency.

Obtained equations are valid for all schemes of regenerative process in a reheat cycle when the regeneration schemes in low- and high-pressure stages are independent of each other. However, when bleeding is performed at both pressure stages, effects on thermal efficiency of the boiler must be taken into account.

Further, author considers reheating and determines the optimum starting temperature. In a reversible reheat-nonregenerative cycle this starting point results in a cycle with maximum thermal efficiency. For actual reheat-regenerative cycle it can only serve as a criterion of cycle quality. The application of the derived expressions to reheat-regenerative cycle with two-stage reheating is mentioned briefly.

A numerical example and a method of cycle comparison supplemented by curves and a table are given.

Author feels that the presented analysis should be of value in work with turbogenerator plants. I. A. Black, USA

1910. Prokhorov, S. A., Approximate calculation of the specific consumption of heat for large turbine installations (in Russian), *Teploenergetika* **3,** 3, 56-57, Mar. 1956.

1911. Leist, K., and Graf, K., Small gas turbines used in vehicles, *Dtsch. Versuch. Luftfahrt E. V. Rep.* no. 7, 104 pp., June 1956.

1912. Land, T., and Barber, R., Suction pyrometers in theory and practice, *J. Iron Steel Inst. Lond.* **184,** 3, 269-273, Nov. 1956.

1913. Hobson, G. D., and Mrosovsky, I., Material balance above the bubble point, *J. Petr. Technol.* **8,** 2, 57-58, Nov. 1956.

Heat and Mass Transfer

(See also Revs. 1738, 1739, 1789, 1790, 1898, 1909, 1913, 1969)

1914. Masters, J. I., and Stein, S., Effect of an axial cavity on the temperature history of a surface heated slab, *Rev. sci. Instrum.* **27,** 12, 1065-1069, Dec. 1956.

Authors describe theoretical study of the error involved in measuring surface temperatures of thick bodies by means of transducers (or thermocouples) inserted into small holes whose depths terminate near the surface. Account is taken specifically of the effect of the hole in distortion of the surface temperature. The analysis is approximate, yielding order of magnitude and bounding values of the incurred error. Surface boundary conditions comprising constant heat flux, parabolic heat flux, and heat flux of constantly increasing slope are treated. R. M. Drake, USA

1915. Salceanu, C., and Bojin, S., Thermal conductivity measurement of gases and vapors (in French), *C. R. Acad. Sci. Paris* **243,** 3, 237-239, July 1956.

1916. Ross, A. D., Heat flow in the steam curing of concrete products, *Proc. Instn. civ. Engrs.* **5,** 6, 695-702, Nov. 1956.

The beneficial effects of steam-curing on the growth of strength of a concrete product might appear to diminish with increasing size of the product. Paper describes an investigation which has shown that although the internal temperature/time and temperature/space gradients differ widely, the integral of temperature and time for a particular treatment actually increases somewhat with increasing size. The heat of hydration of ordinary Portland cement accelerates the rise in temperature but its effects are secondary in importance. From author's summary

1917. Morgan, G. W., and Warner, W. H., On heat transfer in laminar boundary layers at high Prandtl number, *J. aero. Sci.* **23,** 10, 937-948, Oct. 1956.

The behavior of boundary-layer equations for high Prandtl numbers is investigated by generalizing a method given earlier by Schuh [AMR **6,** Rev. 3152] in a particular case of forced-convection flow. An extension to problems of free convection is also given. The boundary-layer equations become independent of Prandtl number by a suitable transformation using new dependent and independent variables. These are obtained from original values by multiplying with a suitable power of Prandtl number. Authors demonstrate their method by deriving the Prandtl number dependence of skin friction and heat transfer in a number of fundamental cases. Some of the results are already known, but others are new, among them those for the rotating disk and the flow in a converging channel, which are treated extensively. Reviewer remarks that in free-convection flow both momentum and energy equation depend on each other and, in the present asymptotic approach, they should be independent of the Prandtl number in the entire range of variables

because conditions are given at both boundaries of range of independent variable. Authors' contention that only that part of momentum equation which lies within thermal boundary layer need be considered for asymptotic high Prandtl number solutions has not been satisfactorily proved in case of free-convection flow.

H. Schuh, Sweden

1918. Reshotko, E., Simplified method for estimating compressible laminar heat transfer with pressure gradient, *NACA TN* 3888, 16 pp., Dec. 1956.

In this report an approximation is made in the method of *NACA TN* 3326 [AMR **8**, Rev. 2808], which simplifies the calculation of heat transfer. Good agreement with the method of *NACA TN* 3326 is expected for isothermal surfaces with adverse and small favorable pressure gradients regardless of surface temperature and also for flow with large favorable pressure gradient over highly cooled surfaces. From author's summary by D. W. Dunn, Canada

1919. Hsu, N. T., Sato, K., and Sage, B. H., Temperature gradients in turbulent gas streams. Effect of flow conditions upon eddy conductivity, *Indust. Engng. Chem.* **48,** 12, 2218–2223, Dec. 1956.

Authors apply Reynolds and Kármán's equations for eddy viscosity and eddy conductivity in steady uniform transfer. For the eddy viscosity, authors suggest the use of Rannie-Dunn's proposed equation for y^+ smaller than 26.7, whereas for bigger values of y^+, they propose the use of the familiar logarithmic distribution expression. To determine the eddy conductivities and viscosities, authors used uniform transfer conditions. The experimental set-up consisted in two parallel copper plates, 13 ft long by 12 in. wide, at a distance of about 0.75 in. Air was permitted to flow between them, while circulating oil behind the plates maintained both boundaries at different temperatures. After 1 ft of travel, a uniform temperature distribution was found in a plane parallel to the plates. A 1-mil resistance thermometer and a calorimeter were used. The temperature gradients and the thermal flux were used to determine the eddy conduction, and care was taken to determine the amount of errors involved.

Experimental values were obtained for Reynolds numbers ranging between 5000 and 60,000, computed with the average kinematic viscosity, the equivalent diameter, and the average velocity. The total conductivity (eddy + thermometric) was plotted against distance across the plates, and showed a minimum at the center and two maxima, of which the sharpness increased with *Re*.

Eddy conductivities and eddy viscosities were presented in graphical form, as well as a graph of eddy Prandtl numbers (eddy viscosity divided by eddy conductivity). The latter showed that, for different positions in the channel, a maximum for *Re* in the range of 10,000 to 20,000 was obtained, and there was a further decrease for higher values of *Re*.

Experiments showed that the total resistance to thermal transport decreases rapidly with the increase in *Re*.

A. Balloffet, USA

1920. Goldberg, M. A., Investigation of the temperature distribution and thermal stresses in a hypersonic wing structure, *J. aero. Sci.* **23,** 11, 981–990, Nov. 1956.

Subject is analyzed at mid-span and mid-chord assuming a sinusoidal thermal-flux versus time-function for various exposure times, and geometric ratios. Major attention is given to thermal analysis since assumptions lead to trivial stress solution. Past work is summarized and effects of assumptions are discussed. Results are presented in convenient charts.

Reviewer questions engineering significance of stress occurring at one point in a complex structure, particularly when interactions from remainder of structure have not been considered. Reader is not advised how effects at this location compare with those at other locations or how effects may combine. An even more approximate thermal solution combined with a more inclusive, not necessarily more complex, stress analysis could lead to more significant engineering results if well coordinated.

W. E. Cooper, USA

1921. Dennis, S. C. R., and Poots, G., A solution of the heat transfer equation for laminar flow between parallel plates, *Quart. appl. Math.* **14,** 3, 231–236, Oct. 1956.

A liquid with unit temperature at $x = 0$ flows between zero temperature walls ($x > 0$, $y = 0$, and $y = \pi$) with a Poiseuille velocity profile. By a y-coordinate Fourier analysis of the temperature field, an infinite set of ordinary differential equations for the coefficients is obtained. When the Péclet number is large the determinantal eigen-equation has dominant diagonal terms so that the eigenvalues and the Fourier expansions of the eigenfunctions can be found by iteration. The expansion of the temperature distribution at $x = 0$ in terms of eigenfunctions is found by a variational method. Detailed figures are given for infinite Péclet number.

There are several misprints. A. F. Pillow, Australia

1922. Hyman, S. C., A note on transpiration cooling, *Jet Propulsion* **26,** 9, p. 780 (Technical Notes), Sept. 1956.

An approximation to the transpiration cooling problem is solved with the assumptions: (1) the coolant and wall temperatures are locally the same; (2) the heat flow rate parallel to the wall is negligibly small compared to that perpendicular to the wall, i.e., the thermal flow problem is one-dimensional; (3) the hot-gas side convection coefficient is known. Simple formulas well-adapted for easy engineering use are obtained for the temperature drops between the hot gas and the outside surface of the wall, the outside and inside surfaces of the wall, and the inside surface of the wall and the ambient coolant. E. V. Somers, USA

1923. Ferrari, C., Effect of Prandtl number on the heat-transfer properties of a turbulent boundary layer when the temperature distribution along the wall is arbitrarily assigned, *ZAMM* **36,** 3/4, 116–135, Mar./Apr. 1956.

The heat-transfer properties of compressible flow over a flat plate, maintained at any arbitrarily assigned state of temperature along its surface, are examined with particular attention directed to the role that the Prandtl number plays in governing such a transport process. This investigation is an extension both in scope and detail over the analysis presented in *Cornell aero. Lab. Rep.* CM-807, so that now the explicit way the Prandtl number influences the local Nusselt number is brought out, and the restrictions limiting the range of this parameter have now been removed.

The local heat-transfer rates, at the surface of the plate, are obtained as before in the form of a definite integral, with the integrand exhibiting the prescribed temperature gradients along the wall, but now the Prandtl number can be demonstrated to be a dominant factor in controlling the final effect on the local Nusselt numbers.

From author's summary by R. H. Eustis, USA

1924. Doroshchuk, V. E., Investigation of heat transfer in a narrow annular space (in Russian), *Teploenergetika* **3,** 1, 14-16, Jan. 1956.

Author describes experimental investigations of heat transfer by convection, in a narrow annular space, from an inner wall tube to surrounding air of an outer wall tube. Ratio of outside to inside diameters is 1.1, with Reynolds number ranging from 20,000 to 220,000. From author's summary by W. Green, USA

1925. Brauer, H., Flow and heat transfer in falling liquid films (in German), *VDI-Forschungsheft* **22,** 457, 40 pp., 1956.

Author studied experimentally the downward flow of a liquid outside a vertical tube under gravity. Three regimes were noted:

(1) laminar with smooth liquid surface, (2) laminar with surface waves or ripples, (3) turbulent. To cover a range of viscosity, various glycol-water mixtures were used, and to cover a range of surface tension sodiumdodecylsulphonate was added to the water. Author studied in particular regime (2), and useful information was obtained about the origin and nature of surface waves, and their quantitative dependence on various flow parameters. Of lesser value seem to be the measurements of wall shear stress, and the theory of heat transfer deduced from these measurements. The shear stress was deduced from the convection loss from an electric heating element in the tube surface, and it appears that any deductions made about the shear stress or heat transfer must involve a circularity of argument. Y. R. Mayhew, England

1926. Dussourd, J. L., and Shapiro, A, H., A deceleration probe for measuring stagnation pressure and velocity of a particle-laden gas stream, 1955 Heat Transfer and Fluid Mech. Inst., Univ. Calif., Los Angeles, June 23–25. Pap. 20, 35 pp.

The measurement of the stagnation pressure and, from this, the velocity of the gas phase in a stream of gas laden with liquid droplets or solid particles is investigated theoretically and experimentally.

The theoretical findings are checked by the testing of a series of experimental probes of varying geometry in an air stream carrying water droplets. It is shown that a practical probe can be built to give a negligible error in the measurement of stagnation pressure in the range of variables investigated.

Further, it is found possible, with simple modifications, to adapt the experimental probe conveniently to the local measurement of other stream properties, namely, the mass rate of flow per unit area of particles, the particle size, and the particle velocity.

From authors' summary by G. H. Lean, England

1927. Vodicka, V., Laminated circular cylinder in a field of periodic temperature variations (in German), *ZAMP* **7,** 5, 422–427, 1956.

Paper treats the propagation of heat waves in an infinite hollow multilayer cylinder subjected to periodic variations of temperature. The hub of this important problem lies in multiplying certain two-by-two matrixes together. The results are very complicated.

From author's summary by F. Krupka, Czechoslovakia

1928. Bevans, J. T., Vertical free convection from an isothermal surface, *Indust. Engng. Chem.* **49,** 1, 114–119, Jan. 1957.

1929. Hatch, T. F., and Barron-Oronzco, D., Air flow in free convection over heated bodies, *Heat. Pip. Air Condit.* **28,** 10, 117–123, Oct. 1956.

The material in this paper can be used as a basis for determining exhaust ventilation requirements for hot processes in industry. Reported are the results of a laboratory study of free convection flow past heated bodies, the objective of which was to relate the magnitude of flow at various distances above the hot body and, more particularly, to its rate of convective heat release. It was desired to express the relationship in the form of a general equation by means of which the design engineer could estimate the cross-sectional dimensions, velocity, and over-all rate of flow of the rising air stream at any desired distance above a given piece of hot process equipment where an exhaust hood was to be placed.

From authors' summary

1930. Fraser, J. P., and Oakley, D. J., Turbulent free-convection, heat-transfer rates in a horizontal pipe, ASME Fall Meet., Denver, Colo., Sept. 1956. Pap. 56–F–6, 7 pp.

Turbulent free-convection heat transfer was measured in a horizontal pipe 10 ft long and 8-in. in diameter, closed on both ends, heated electrically at one end, and cooled by a water jacket on the other end. The pipe was filled with liquid sodium. Heat input was measured electrically and heat output calorimetrically. Temperatures were determined by wells extending 1 in. into the pipe at the top, bottom and sides. It was found that the temperatures decreased approximately linearly from the hot to the cold end of the pipe and that a temperature difference of approximately the same amount as between the hot and cold end existed in any cross section between the upper and the lower thermocouples. The heat transfer in the liquid metal from the hot to the cold end of the pipe was found to increase proportionally to the temperature difference at both ends raised to the power 3/2. Heat-transfer rates were quite high. The actually measured heat-transfer rates were up to 600 times the heat flow calculated for pure conduction.

An approximate calculation is also presented on convective heat transfer in a pipe inclined towards the horizontal, closed on one or both ends and heated on the lower end. It is based on the concept that two streams in opposite directions exist in the upper and the lower half of the pipe and that the velocity is determined by a balance of buoyancy and friction forces.

E. R. G. Eckert, USA

1931. Cole, R., Investigation of transient pool boiling due to sudden large power surge, *NACA TN* 3885, 44 pp., Dec. 1956.

A thin nickel ribbon placed in a pool of water at atmospheric pressure at temperatures from 76 to 200 degrees Fahrenheit was electrically heated for 30 milliseconds with different power inputs. Time temperature variations and photographs of the transient bubble formation are given in the report. Heat fluxes to 3 million Btu per hour per square foot were used.

M. Tribus, USA

1932. Nishikawa, K., Studies on heat transfer in nucleate boiling, *Mem. Fac. Engng. Kyushu Univ.* **16,** 1, 1–28, Nov. 1956.

Data are presented showing the influence of liquid depth on the heat-transfer coefficient and temperature profiles in water and several organic fluids at atmospheric pressure. The various boiling correlations are reviewed and a new one proposed based on an "effective stirring length for the bubble" and the usual liquid and vapor properties. All fluids fall within approximately ±20% of a dimensionless curve which is essentially $(q/A)\,(\Delta T)$ versus q/A. As the principal independent variable, q/A, appears to the same power in both coordinates and the curve slopes up to the right at a slope close to one, reviewer does not consider the plot a sensitive test of the correlation. W. M. Rohsenow, USA

1933. Volkov, N. P., Increasing the reliability of the evaporative heating surface of economizers (in Russian), *Teploenergetika* **3,** 2, 51–53, Feb. 1956.

1934. Suraev, A. P., Deaeration of feed water (in Russian), *Teploenergetika* **3,** 1, 39–41, Jan. 1956.

1935. Rohsenow, W. M., Heat transfer and temperature distribution in laminar-film condensation, *Trans. ASME* **78,** 8, 1645–1648, Nov. 1956.

Condensation at the pure liquid-vapor interface gives rise to cross flow of fluid in the continuous laminar film flowing along a wall. Energy effects associated with the cross flow are calculated and corrections obtained for temperature distribution in the film, local film thickness, and mean heat-transfer coefficient h_m. The increase in heat-transfer coefficient is usually given by the term $[1 + 0.68(c\Delta t/b_{fg})]^{1/4}$, where c is specific heat, Δt is temperature drop across film, and b_{fg} is the latent heat. Earlier treatment by Nusselt gave 0.375 instead of 0.68. M. Gilbert, USA

1936. Rohsenow, W. M., Webber, J. H., and Ling, A. T., Effect of vapor velocity on laminar and turbulent-film condensation,

Trans. ASME **78,** 8, 1637–1643, Nov. 1956.

Condensate film flowing under gravity influence is analyzed for effect of vapor shear stress at interface. The transition Reynolds number for laminar to turbulent film flow is found to be diminished, and primarily a function of the dimensionless vapor shear stress. To obtain heat-transfer coefficient for the composite film, turbulent region is assumed (1) to obey usual three-region universal-velocity-distribution law of Prandtl-Nikuradse for friction velocity as a function of friction distance parameter, (2) to have equal heat and momentum diffusivities. Theoretical relations for the heat transfer as a function of Prandtl, Reynolds number, and vapor shear stress are in agreement with earlier empirical equation of Carpenter and Colburn and provide basis for future experimental work.

M. Gilbert, USA

1937. Argyropoulos, T. G., Direct solution of the heat-balance equation for thermal anti-icing systems, *Aero. Engng. Rev.* **16,** 2, 60–63, Feb. 1957.

A nomographic method for solving these equations is presented.

M. Tribus, USA

1938. Ferrand, G., The problem of freezing in penstocks (in French), *Houille blanche* **11,** 2, 275–281, May/June 1956.

1939. Aroeste, H., Theory of melting and yield strength; Deformation and flow of solids, Colloquium Madrid, Sept. 26–30, 1955, 184–186; Berlin, Springer Verlag, 1956.

Author presents a modified version of Fürth's [AMR **3,** Rev. 2305] suggestion of relating the rupture strength to the melting of metals, which he considers as a breakup of a block structure. Fürth assumes that the block structure is an intrinsic feature of the crystal lattice. By treating process of breaking on a thermodynamical basis Fürth attempts to by-pass the necessity of referring this problem to a detailed mechanism of fracture.

Present author proposes to correct Fürth's relation $Q/\Lambda \simeq 6d/L$, where Q is heat of melting, Λ is sublimation heat, d is the interatomic distance, L is the linear dimension of the blocks, with the critical yield stress obtained by considering Frank-Read mechanism for yielding. The yield strengths derived in this way are at least an order of magnitude too high.

In reviewer's opinion the approach accepted in this paper brings back the problem of actual mechanism of fracture contrary to the purpose of Fürth's paper. On the other hand, a proposed model of mechanism of fracture seems to be over simplified.

Note: It appears that there are two misprints: in equation (9) where σ is missing in the numerator, and in equation (5) μ in the denominator should be replaced by π.

W. Sylwestrowicz, USA

1940. Drayer, C., A short description of a thermal de-icing system (in Dutch), *Ingenieur* **68,** 32, 21–25, Aug. 1956.

The variation of the point-unit thermal conductance at the skin of an airfoil is discussed. The results of investigating the influence of the entrance conditions on the point- and average-unit thermal conductance are mentioned.

From author's summary

1941. Jenness, J. R., Jr., Method for measurement of the rate of drying of surface coatings, *J. appl. Phys.* **27,** 11, 1371–1373, Nov. 1956.

By observation of rolling friction effects, the rate of drying of paints, varnishes, and other surface coatings can be evaluated more precisely than by previous methods. The time of descent of a ball rolling down a coated incline has been proposed as an index of surface condition. The basic physical phenomenon involved, however, is rolling friction, so the coefficient of rolling friction would be preferable for use as a standard. A metric analogous to Brinell hardness can be defined from the coefficient of rolling friction. The ratio between the coefficient of rolling friction and the radius of the test ball is proposed as an index of surface condition.

Included is an analysis of the motion of a sphere falling off the edge of a flat level table top and data on drying of spar varnish.

W. M. Rohsenow, USA

1942. Zaromb, S., An analysis of diffusion in semiconductors, *IBM J. Res. Dev.* **1,** 1, 57–61, Jan. 1957.

The equations of motion for diffusion of charged particles have been formulated and specified in order to treat diffusion of donors and acceptors in a semiconductor. The equations—neglecting the electrical space charge—are discussed for the special case of dominant intrinsic conductivity. It is shown that compound formation or association between donors and acceptors will formally lead to a diffusion-coefficient strongly dependent on concentration.

As pairing between acceptors and donors is theoretically probable and has been shown to occur experimentally, the *a priori* assumption of the validity of Fick's first law[i.e., constant D], which has usually been assumed for the diffusion of impurities in semiconductors, is not valid.

The concentration dependence of the diffusion coefficient due to this cause could be the explanation for some discrepancies in the experimental results reported so far. This is possible since, in determining diffusion coefficients, an evaluation usually is based upon the validity of Fick's first law.

H. J. Oel, Germany

1943. Diaguila, A. J., and Livingood, J. N. B., Rapid determination of core dimensions of crossflow gas-to-gas heat exchangers, *NACA TN* 3891, 19 pp., Dec. 1956.

The design of core most suitable to any given heat-transfer application cannot always be specified readily and, hence, in a design study, various configurations must be considered. Paper is a development of the graphical procedure for determining optimum core dimension given earlier [AMR **9,** Rev. 3083] to avoid the necessity of drawing separate charts for each configuration or condition.

Illustrations of the use of the method are given.

G. G. Thurlow, England

1944. Hartel, S., Losses due to leakage in air preheaters (in German), *Brennstoff-Wärme-Kraft* **8,** 10, 494–496, Oct. 1956.

1945. Parmelee, G. V., Vance, P., and Cerny, A. N., Analysis of an air-conditioning thermal circuit by an electronic differential analyzer, *Heat. Pip. Air Condit.* **28,** 9, 117–123, Sept. 1956.

The electronic differential analyzer with its associated input generators and recorders is found to be capable of solving a complex thermal-circuit problem with an accuracy entirely suitable for making detailed analyses of the behavior of air-conditioning thermal systems, expressed in the form of thermal-circuit diagrams. The combination of the thermal-circuit technique and the computational ability of a differential analyzer shows itself to be a powerful tool in solving the complex air-conditioning thermal problems. It is regrettable that the electrical circuit analog is not as systematically applied to heat-transfer problems as it has been applied, in the past decades, to mechanics, hydraulics, and acoustics. In heat-transfer investigations, partial differential equations are always involved and, with usually irregular boundary conditions, these problems are mostly unsolvable. Thus the thermal-circuit technique with the aid of a differential analyzer could be an invaluable help.

The analyzer is suitable for handling systems of greater complexity, but additional operational amplifiers would be needed. It is evident that cost must place a practical limit to the number

which could be used. Limitations are closely related to the fineness of the capacitance lumping required. Though there has been as yet no rational way of determining the lumping requirements for any given problem, the question of the necessary minimum number of lumps and of their most effective distribution along a circuit branch was recently investigated and substantial progress was made. From authors' summary

1946. Kadirov, N. B., On the determination of the temperatures of the working fluids and heating surfaces in heat exchangers (in Russian), *Trudi Azerb. industr. in-ta.* no. 9, 82–97, 1955; Rev. no. 897, *Ref. Zh. Mekh.* 1956.

A number of elementary equations are put forward from which the temperatures of the heat carriers and walls can be determined.

Author makes allowance for the relationship between the coefficient of heat conductivity of the metal and the temperature. This, although a complication, is justifiable and necessary, since the temperature gradient in a metal is very small, while the thermal resistance of the metal is relatively low.

Courtesy of Referativnyi Zhurnal A. A. Gukhman, USSR
Translation, courtesy Ministry of Supply, England

1947. Shubin, E. P., Method for the approximative solution of transcendental equations in the calculation of heat exchangers (in Russian), *Teploenergetika* **2,** 11, 44–50, Nov. 1955.

A tabulated interative method for computing optimum design values for heat-exchanger characteristics and insulated piping.
V. Korolenko, USA

1948. Fukuoka, J., Studies on electrical direct heating, *Kyushu Univ. Res. Inst. appl. Electricity* no. 3, 67–105, 1952.

Paper deals with heating of a solid due to the presence of an electromagnetic field. Starting from the Fourier equation of heat conduction, author studied and obtained solutions for the transient temperature distribution in an isotropic, homogeneous rectangular parallelopiped having an arbitrary initial temperature distribution $\theta_i(x,y,z)$ with heat exchange at its surfaces to an environment at temperature $\theta_a(t)$ which may vary only with respect to time. The internal heat source is represented by an arbitrary function of space and time, i.e., $q = q(x,y,z,t)$. The thermal properties of the material are taken as constants. Consequently, the partial differential equation and the boundary conditions considered are both linear. As is well known, the important dimensionless groups which arise naturally in a problem of this nature are the Biot or the modified Nusselt modulus (G) and the Fourier modulus t/H. [These terminologies, while very common in this country, are not used in the paper.] Attention is directed to bodies having relatively large thermal time constants since electrical heating is more effective in such bodies.

Several one-dimensional cases concerning heating of an infinite plate have been treated in detail. They include (a) uniform heating, (b) surface heating, (c) combined uniform and surface heating, and (d) local heating. The rate of temperature rise and the maximum temperature difference in the plate, as influenced by the time and space control of internal heat generation, are discussed. The time control of internal heat source which varies linearly with temperature is also considered.

While the author considered the general problem of heating due to electromagnetic field using Maxwell's fundamental equations, attention was directed to the practical case of heating of concrete slabs by relatively low frequency current. Under this circumstance, the electromagnetic field results in a simple, conductive current field. Electrodes of the uniform-flow and surface-flow type were analyzed and diagrams were presented which would prove useful in the selection of electrode arrangements. Finally, the theory was applied to the curing of floor concrete in severely cold weather. Results were compared with those obtained by ordinary surface heating. B. T. Chao, USA

1949. Weinberg, S., Controlling temperature rises in a cooled pump circuit, *Engineering* **182,** 4719, 211–213, Aug. 1956.

1950. Beneke, J., Cornell Aeronautical Laboratory vortex free air thermometer, pp. 61–86, Symposium on the vortex tube as a true free air thermometer, Chicago, Ill., Armour Research Foundation, May 1955.

Paper summarizes four years' work for the Navy Bureau of Aeronautics involving the development of a vortex free air thermometer for use on high-speed aircraft. The thermometer is of the uniflow type consisting of a cylinder, open at one end, having a rectangular, tangential inlet near the blind end, and having a small, resistance thermometer probe extending from the blind end into the core of the cylinder. Various types of exhaust nozzle configuration were tested. The research program utilized the "cut-and-try" method. Data presented show effect of exhaust nozzle area and shape, altitude, angle of yaw, and attack on thermometer performance for various thermometer configurations. It is concluded that the best thermometer appears to be insensitive to altitude up to 40,000 ft, essentially insensitive to yaw variations within ±10 degrees, does not deviate more than ±1C for angle of attack variations up to ±6 degrees, and should indicate true free air temperatures within ±1C up to $M = 0.9$. R. J. Mindak, USA

1951. Nicklas, J. P., The vortex tube as an acoustic generator with application to true airspeed measurement, pp. 87–105, Symposium on the vortex tube as a true free air thermometer, Chicago, Ill., Armour Research Foundation, May 1955.

Paper represents a progress report of an investigation of the effect of vortex thermometer geometry and flight conditions on the acoustic properties of the thermometer. For a particular configuration of a tangential inlet uniflow tube, data are presented showing the effect on generated acoustic frequency of free air temperature, Mach number, tube geometry, and altitude. It is stated that the results are preliminary in nature and that considerable additional research would be required to produce a useful instrument utilizing generated acoustic energy as a means of measuring true free air temperature. R. J. Mindak, USA

1952. Schecter, R. M., and Ruskin, R. E., The internal characteristics and probe variables of the NRL axial-flow vortex thermometer, pp. 106–117, Symposium on the vortex tube as a true free air thermometer, Chicago, Ill., Armour Research Foundation, May 1955.

This report comprises a qualitative discussion of the effect of thermometer geometry on the indicated true free air temperature for an axial-flow vortex tube. In this instrument, air enters the housing axially and is deflected into a helical path by means of a stationary curved spinner vane inside the housing. The temperature sensing element is a cylindrical projection extending from the rear of the spinner vane. R. J. Mindak, USA

1953. Ruskin, R. E., and Schecter, R. M., Operational characteristics of the NRL axial-flow vortex thermometer, pp. 118–126, Symposium on the vortex tube as a true free air thermometer, Chicago, Ill., Armour Research Foundation, May 1955.

This is a short qualitative discussion of flight tests of the thermometer reported in the preceding paper. This and the preceding paper should have been combined, saving considerable space devoted to "boiler plate" or background and descriptive material. In reviewer's opinion there wasn't enough worthwhile information in the two papers to warrant the dual presentation.
R. J. Mindak, USA

Combustion

1954. Spalding, D. B., A mixing rule for laminar flame speed, *Fuel* **35,** 3, 347–351, July 1956.

A rule is given for predicting laminar flame speed of mixture of two combustible gases, provided the variation of component flame speed with final temperature is known. The basic assumption is that, in mixture, each component acts as it would if it alone were to burn to the final temperature corresponding to the mixture. A critical examination of this assumption suggests that the rule is only roughly valid. D. G. Martin [see following review] has compared this rule with experimental data. J. Barr, Scotland

1955. Martin, D. G., Flame speeds of mixtures containing several combustible components or a known quantity of diluent, *Fuel* **35,** 3, 352–358, July 1956.

The mixing rule for laminar flame speeds proposed by D. B. Spalding [see preceding review] has been tested with published data, and with new experiments using methane-hydrogen-air mixtures. With the understandable exception of the dry carbon-monoxide-hydrogen system, Spalding's rule predicts flame speeds to within 10%. J. Barr, Scotland

1956. Finch, D., Ignition temperatures of volatiles generated from coal and coal chars, *Fuel* **35,** 4, 415–432, Oct. 1956.

A laboratory apparatus, providing a controllable supply of volatiles for a period of more than 1 hr, has been developed. The volatiles were ignited by means of an electrically heated spiral to give a diffusion flame in air, and measurements were made of ignition temperatures of volatiles emitted from coals and chars. The volatile matter burned as a stable flame provided that the bed temperature was above a minimum value. It was established that the material of the igniting source was important. Thus, when platinum was used, ignition temperatures were in general considerably lower than those obtained with Nichrome and tungsten. When Nichrome was used, ignition temperatures increased with decreasing bed temperature and with increasing volatile content. Ignition temperatures of the volatiles from two chars were lower than those of the volatiles from the parent coals. Catalysis was a frequent phenomenon with platinum. The work has shown that catalytic effects become more pronounced with increasing bed temperature and coal rank. From author's summary

1957. Miller, R. O., Ignition delays and fluid properties of several fuels and nitric acid oxidants in temperature range 70° to −105° F *NACA TN* 3884, 32 pp., Dec. 1956.

1958. Huellmantel, L. W., Ziemer, R. W., and Cambel, A. B., Stabilization of premixed propane-air flames in recessed ducts, *Jet Propulsion* **27,** 1, 31–34, 43, Jan. 1957.

An alternate method of flame stabilization is proposed in an effort to obviate the pressure drop associated with bluff body flameholders. The proposed method consists of using recesses in the walls of the test chamber. Several flameholder contours have been experimented, placing them in the lower and upper walls of the test chamber, thus ascertaining adequate burning of the air and fuel mixture within the length of combustion chamber used.

It is shown that use of such recesses results in a wider range of stabilization limits and higher blow-out velocities as compared to an arbitrary V-gutter flameholder, while indicating a pronounced decrease in the associated pressure drop.

From authors' summary by R. Delbourgo, France

1959. Dalgleish, J. E., and Tischler, A. O., Experimental investigation of a lightweight rocket chamber, *NACA TN* 3827, 11 pp., Oct. 1956.

Experiments have been conducted with a jacketed rocket combustion chamber that was fabricated by hydraulic forming from sheet metal. Rocket combustion chambers made by this method have been used successfully. Runs with these combustion chambers have been made at over-all heat-transfer rates of 2.5 Btu/sq in./sec with water cooling and also with ammonia as a regenerative coolant. From authors' summary

1960. Dorofeyev, V. M., On the thermodynamic theory of the constant-volume combustion turbine (in Russian), *Trudi Kuibyshevsk. aviats. in-ta* **2,** 259–263, 1954; Rev. no. 752, *Ref. Zh. Mekh.* 1956.

An examination of the elementary theory of constant-volume combustion turbines. The temperature distribution along the length of the combustion chamber (axis of the propellant charge) is determined at which a constant discharge velocity is maintained during the exhaust period. M. A. Peshkin, USSR

Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1961. Hicks, J. F. G., Time rate of change of concentration in continuous glass melting furnaces, *Bull. Amer. ceram. Soc.* **35,** 12, 469–470, Dec. 1956.

A method of calculating concentrations at the orifice from those in the fill is presented and the agreement between calculated and measured values is found to be satisfactory.

From author's summary

1962. Gurvich, A. M., and Kuz'min, N. V., Degree of black surface in grate-type furnaces (in Russian), *Teploenergetika* **2,** 11, 16–19, Nov. 1955.

Authors offer a new formula for calculating degree of black surface in a grate-type furnace. Formula takes into account the glowing effect of a layer of solid fuel upon heat transfer.

From authors' summary by W. Green, USA

1963. Browning, J. A., Tyler, T. L., and Krall, W. G., Effect of particle size on combustion of uniform suspensions, *Indust. Engng. Chem.* **49,** 1, 142–147, Jan. 1957.

The lean limit of stable combustion of sprays and solid suspensions is mainly dependent on the range of particle size and on the air turbulence. Operational experience and experiments indicate that stability of combustion in the lean range may be improved, and the air-fuel range increased, by better control of particle size. Turbojet systems containing a portion of large droplets show a greater stability. Previous experiments by Dreyhaupt (1942) and Burgoyne and Cohen (1954), and others, showed that, e.g., the low limit of 26: 1 air-fuel ratio for 10-micron drops was increased to 64:1 air-fuel ratio for 55-micron drops. The test results of various investigators, however, were not comparable, because different fuels were used.

In the present experiments, solid wax particles were used producing suspensions whose characteristics are quite similar to those of liquid suspensions. These solids are easily handled and, using them, a wider range of experimental knowledge can be obtained. Using Armowax wax, a methylene bistearamide, authors produced powders having eleven accurately defined size ranges, from 10 micron to 110 micron, by means of an elutriation apparatus. A special combustion bomb was used, in which the air-powder suspension was agitated by means of a blower propeller, in order to insure a uniform mixture. Several ignition methods were investigated. The intense arc formed after vaporization of a small metal wire was found most satisfactory. Each size fraction of Armowax powder has been tested for its low limit of flammability and pressure-concentration curve, and curves of maximum pressure were drawn. The maximum pressure is inversely proportional to particle size. Larger particle sizes sustain high pressures over a greater

fuel concentration range than do the small particles.

Explanations on theoretical basis, and on assumptions, have been made for the various findings. Particle size of about 60-micron diam produced the most systems for the lean limit of flammability; both smaller and larger sizes are less favorable. Some important questions arise: What role does the fuel volatility play? Is there a maximum size particle above which combustion rates are so low as to be impractical in commercial devices? Further experiments should clear up these important problems.

K. J. DeJuhasz, Germany

1964. Feeley, F. G., Jr., Fly-ash refiring, *Trans. ASME* **78,** 8, 1747-1755, Nov. 1956.

Ballistics, Detonics (Explosions)

(See also Revs. 1684, 1693, 1697)

1965. Moore, G. E., and Berman, K., A solid-liquid propellant system, *Jet Propulsion* **26,** 11, 965-968, Nov. 1956.

Authors describe self-igniting hybrid rocket burning 90% hydrogen peroxide and polyethylene. Report reviews original stimulus for system, propellant choice, and results of 300 tests.

System has: (1) Specific impulse (theoretical) 228 lb-sec/lb; (2) high density 1.34 g/cc; (3) spontaneous ignition by decomposing H_2O_2; (4) throttling by control of peroxide valve; (5) monopropellant simplicity, safer; (6) no hard starts.

Authors conclude: "The combustion itself shows remarkable stability under all conditions, including very low chamber pressures and very low pressure drops. It appears, in fact, that the burning solid fuel is its own flameholder and a very stable one. This conclusion is supported by photographic evidence obtained with small transparent hybrid engines."

F. I. Given, USA

1966. Nelson, R. L., The motions of rolling symmetrical missiles referred to a body-axis system, *NACA TN* 3737, 51 pp., Nov. 1956.

Linearized equations of motion are analyzed for a rolling missile having slight aerodynamic asymmetries. An attempt is made to evaluate some of the stability derivatives through application of the derived stability roots to oscillation data obtained in flight using four accelerometers in a rolling symmetrical missile. Calculations are also presented for the motions produced by other types of forcing functions.

Reviewer criticizes the Magnus force or moment derivative symbol definition as being mathematically improper and physically incorrect. For example, the correct definition for $C_{n_{p\alpha}}$ should be $\partial C_n/\partial p\alpha$ or even $\partial C_n/p\partial\alpha$ but not $\partial C_n/\partial p\partial\alpha$, as given. The rate of roll (p) cannot be a differential in these linearized equations of motion.

E. V. Laitone, USA

Soil Mechanics, Seepage

(See also Revs. 1785, 1786, 1969, 1970, 1971, 1972, 1973, 1975, 1976)

1967. Pickett, G., Further studies of stresses in the subgrade under a pavement, *J. Technol.* **1,** 1, 35-41, June 1956.

Paper extends earlier results of Pickett and Ai [*Proc. Highway Res. Board,* 121-129, 1954] in which stresses in subgrade are determined by using plate theory for pavement and theory of elasticity for subgrade. The present solutions are complementary to, and depend to some extent upon, Burmister's more exact treatment of two-layer systems.

R. E. Gibson, England

1968. Kolmogorov, R. I., A qualitative assessment of the regions of soil compaction in pile sinking (in Russian), *Trudi Leningr. in-ta inzh. vodn. transp.* **21,** 84-95, 1954; Rev. no. 1065, *Ref. Zh. Mekh.* 1956.

Experiments were made on models of the shape and size of the compaction regions forming around piles driven into dry, screened sand. During sinking of the piles, the following regions were observed and measured: *a* upward thrust; *c* lateral displacement; *d* and *e* downward displacement along curved and straight paths, respectively. (Printing errata-p. 88, l. 12 from above, should be Δb instead of Δb; p. 89, l. 22 from above, should be "*e*" instead of "*b*").

The experiments have shown that the ratio of maximum width of the compacted zones in the soil to their depth is of the order of 1.65 to 1.75. During sinking, the dimensions of the regions tend to become constant; in loose sand the critical depth is $5b$, where b is the width (diameter) of the pile. The dimensions of the regions increase with increasing density of the sand; around a blunt-pointed pile these regions are larger than around a sharp-pointed pile. Around solitary piles, the regions *a, c, d,* and *e,* are clearly marked. In the simultaneous driving of a number of piles, no *e* zone is formed; instead, rhomboid regions of undisplaced soil form between the individual piles. The distance between hanging piles is, according to GOST 5305-50, para. 11, $6b$, which is insufficient, and the minimum spacing should be of the order of $10b$.

G. I. Ter-stepanyan, USSR

Courtesy of Referativnyi Zhurnal

Translation, courtesy Ministry of Supply, England

Micromeritics

1969. Day, P. R., Dispersion of a moving salt-water boundary advancing through saturated sand, *Trans. Amer. geophys. Un.* **37,** 5, 595-601, Oct. 1956.

Dispersion of salt in water flowing through a bed of sand is measured. At the bed inlet, the water feed is replaced, for a finite time, by salt solution. The concentration-time graph at the bed outlet can be predicted by assuming an appropriate diffusion coefficient D in the direction of flow. Author assumes D will be the same in all directions, although Kramers and Alberda [*Chem. Engng. Sci.* **2,** 1, 173-181, 1953] report a much smaller diffusion coefficient normal to the flow ($D/10$). This assumption does not affect author's results.

J. F. Davidson, England

1970. Burlay, I. F., The equations of motion of subsoil waters (in Russian), *Sbornik geol. geogr. fak. Odessk. un-ta* **2,** 153-173, 1954; Rev. no. 968, *Ref. Zh. Mekh.* 1956.

The problem is analyzed of the so-called "section porosity" of the subsoil, giving the derivation of expressions for the known correction factor α representing the irregularity of the velocity distribution in the active cross section for the case of subsoil waters. The usual Bernoulli equation is stated for subsoil waters, embodying the effect of the velocity head; finally, derivations are given for the equations of irregular and unsteady flow of subsoil water with allowance for the velocity head.

The latter derivations differ from those usually quoted in the textbooks (for the case of open streams), essentially in that the author, examining the case of subsoil waters, allows for the loss of head by the Darcy formula, and not the formula of Chaizy, which applies to open channels.

It should be noted that author, in considering the laminar flow of subsoil water, makes an allowance for the negligibly small value of the kinetic energy of the flow; he erroneously concludes, however, that consideration of the kinetic energy in the case of the flow of subsoil waters is necessary because of the fact that the correction term above-mentioned is greater than in the case of tur-

bulent flow of water in open channels.
Courtesy of Referativnyi Zhurnal R. R. Chugaev, USSR
Translation, courtesy Ministry of Supply, England

1971. Kussakov, M. M., Kosheleva, I. M., and Mekenitskaya, L. I., On methods for the investigation of seepage through uncemented porous media (in Russian), *Trudi Mosk. neft. in-ta* no. 14, 155-166, 1955; Rev. no. 969, *Ref. Zh. Mekh.* 1956.

Experimental results are given for the measurement of the rate of seepage of unpolarized and polarized liquids through an uncemented, porous medium.

It is demonstrated that the addition of polarized components to hydrocarbon liquids can both increase and decrease the rate of steady-state filtration. The experiments were made with two models of a porous medium, prepared from glass and quartz powders. The unpolarized hydrocarbon liquids employed were mixtures of medicinal paraffin and ligroin.

The following fundamental conclusions have been reached:

(1) The results of measurements of the permeation of uncemented glass powders are independent of the viscosity of the unpolarized hydrocarbon permeating liquid.

(2) With the addition of oleic acid to the unpolarized liquid, the volume rate of seepage and permeability diminish the more considerably, the greater the state of dispersion of the particles of the powder.

(3) With the addition of petroleum to the unpolarized liquid, the seepage rate increases in the region of low concentrations, while the seepage of pure petroleum shows a considerably lower rate than in the case of an unpolarized liquid, or isoviscous petroleum.
Courtesy of Referativnyi Zhurnal E. M. Minskii, USSR
Translation, courtesy Ministry of Supply, England

1972. Nasberg, V. M., Generalized formula for the filtration calculation of a non-pressurised ideal well (in Russian), *Izv. Tbilis n.-i Inst. Sooruzh.* 1. *Gidroenergetiki* no. 7, 37-56, 1954; Rev. no. 313, *Ref. Zh. Mekh.* 1956.

The problem is examined of the axially symmetrical non-pressure motion of ground waters poured into an ideal well. It is assumed that the motion of the ground waters is subject to a binomial dependence of the Prony type. The calculation is based on the Dupuis hypothesis (problem of flow to a well in this arrangement was examined by reviewer).

The equation of the depression curve is brought to a differential equation of the Riccati type, and an example is given of the numerical integration of this equation according to the Runge-Kutta method. Further, the author examines the physical significance of coefficients in a binomial formula of the law of resistance as applied to fissured rocks. A comparison is given of the depression curve obtained by numerical integration with depression curves plotted on the assumption of the Darcet law (Dupuis) and of the quadratic law of resistance (Krasnopolsky).
Courtesy of Referativnyi Zhurnal G. K. Mikhailov, USSR
Translation, courtesy Ministry of Supply, England

1973. Zaks, S. L., and Burmistrova, V. F., Investigation of the physical properties of weakly cemented petroleum gas containing strata (in Russian), *Trudi Inst. Nefti Akad. Nauk* no. 3, 223-230, 1954; Rev. no. 325, *Ref. Zh. Mekh.* 1956.

Methods are described for determining total porosity, absolute permeability, and minimum content of bound water in weakly cemented strata used in the petroleum institute of the AN.SSSR.
Courtesy of Referativnyi Zhurnal G. K. Mikhailov, USSR
Translation, courtesy Ministry of Supply, England

1974. Gordienko, P. I., Filtration of water through linings of broken stone (in Russian), *Sb. Trudi Mosk. inzh.-stroit. Inst.* no. 9, 124-133, 1955; Rev. no. 318, *Ref. Zh. Mekh.* 1956.

The results are given of the experimental investigation of filtration in detritus and pebbles of a mean diameter of 0.5 to 5 cm. The gradients of the filtration flow in the tests varied within the limits of 0.004 to 0.7; the total number of tests (for 5 specimens of linings) exceeded 180.

The treatment of the test results was effected on the assumption of a stage law of filtration of the Krober type, although the numerous investigations in recent decades have completely confirmed the binomial formula for the resistance law in filtration. The author's attempt to connect the exponent in the expression of the stage law with the mean diameter of the lining was unsuccessful, although certain rough empirical formulas were assumed by him. The relationship of the filtration coefficient with the mean diameter was also examined. In this case, the results of other investigators were also used. Author largely bases himself on the work of S. V. Izbash, "The filtration in coarse grain material."
Courtesy of Referativnyi Zhurnal G. K. Mikhailov, USSR
Translation, courtesy Ministry of Supply, England

1975. Shmyglya, P. T., The leakage of a liquid through penetrable layers to the roof and to the floor, in the case of rectangular and radial filtration (in Russian), *Trudi Mosk. neft. Inst.* no. 14, 230-241, 1955; Rev. no. 315, *Ref. Zh. Mekh.* 1956.

The problem is examined of filtration in a seam of large dimensions in plan, during leakage from it into adjacent seams which are separated from it by thin, feebly penetrable layers. For solving this problem, on the assumption of the constancy of the potential along the verticals, use was made of methods developed by A. N. Myatiev, *Izv. Akad. Nauk SSSR Otd. tekh. Nauk* no. 9, 1947. Equations are given for rectilinear and axially symmetrical motion of a liquid. For the first case, an approximate solution is compared as an example with the available precise solution of V. N. Shchelkachev and M. A. Gusein-Zade. An accurate solution for the second case, that of radial filtration, is given in M. A. Gusein-Zade's work. Author discusses the calculation of certain forced and operational wells in an unlimited stratum, and gives an example.
Courtesy of Referativnyi Zhurnal G. K. Mikhailov, USSR
Translation, courtesy Ministry of Supply, England

1976. Tsarevich, K. A., Piskunov, N. S., Goverova, G. L., and Glebova, T. A., A method of calculating mixed extraction systems (dissolved gas systems with a natural feeding or pumping contour) (in Russian), *Trudi Vses. neftegaz. n.-i. in-ta* no. 6, 190-204, 1954; Rev. no. 960, *Ref. Zh. Mekh.* 1956.

Any oil field, with a specific configuration and arrangement of extraction boreholes, can be divided into elementary sections bounded by equivalent impermeable walls, at which the normal derivative of the potential (pressure) is zero. These sections can be represented by rectangles or sectors containing one or more boreholes.

The motive force of the flow of oil to the borehole(s) in conditions of mixed working is the pressure (head) of the contour water, and the expansion of the occluded gases.

An equation for the material equilibrium can be set up for any such elementary area. The boundary of a region with gasified liquid will be subject to a time variation.

The change in saturation on the contour of the region, at which conditions of dissolved gas operation are initiated, is assumed as the basis for the relationship derived by K. A. Taservich [*Tr. Mosk. neft. in-ta* no. 25, 1947].

Examples are given for setting up the equations of material equilibrium, for different elementary systems.
Courtesy of Referativnyi Zhurnal M. A. Gusein-zade, USSR
Translation, courtesy Ministry of Supply, England

1977. Van Dongen, J. R. J., and Ter Linden, A. J., The application of gas/liquid cyclones in oil refining, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56-A-61, 4 pp.

Geophysics, Meteorology, Oceanography

(See also Revs. 1719, 1928)

1978. Karplus, W. J., and Allder, J. R., Atmospheric turbulent diffusion from infinite line sources: an electric analog solution, *J. Meteor.* **13,** 6, 583–586, Dec. 1956.

Paper describes an electric analog technique for obtaining steady solutions of the diffusion equation for an arbitrary distribution of velocity and diffusivity in the diffusing medium. Detailed results are obtained for atmospheric turbulent diffusion from a line source, placed on the ground perpendicular to the wind, the variation of mean velocity and eddy diffusivity with height being assumed logarithmic and linear, respectively.

I. Proudman, England

1979. Bundgaard, R. C., Computation of streamlines from the pressure field, *J. Meteor.* **13,** 6, 569–582, Dec. 1956.

In most routine weather forecasting, winds are estimated with help of the geostrophic conception. Modern aeronautical operations, however, often require more exact wind data, and a method is wanted which would allow fast routine calculation of the wind field from the measured pressure field.

Author of this paper neglects vertical motions and derives an approximate (transcendental) equation for the deviation angle β between pressure contours and streamlines. The coefficients of this equation can be taken from the geometries of the contours and their variation in time. Solution by successive approximations is laborious even with help of time-saving graphical techniques. The method is thus not suitable for daily routine work but may serve as a further means for qualitative estimates of ageostrophic wind components. Test calculations of streamlines at 500 mb surface and comparison with actual streamlines showed improvement in 41% of all cases. In 17% of all cases the computed streamlines were worse than the contour lines. Apparently, direction only was compared; nothing is said about a wind-velocity test.

H. Merbt, Sweden

1980. Kuo, H.-L., Forced and free meridional circulations in the atmosphere, *J. Meteor.* **13,** 6, 561–568, Dec. 1956.

Mathematical treatment of the maintenance of meridional circulation by heat and momentum sources in the atmosphere is presented. The form and intensity of such circulations are greatly influenced by the mean temperature distribution, the vorticity of the mean zonal flow and a frictional coefficient. The effects of the horizontal eddy transport and frictional dissipation of zonal momentum tend to produce a three-cell meridional circulation in the troposphere with a reverse cell in middle latitudes.

R. O. Reid, USA

1981. Bushby, F. H., and Huckle, V. M., The use of a stream function in a two-parameter model of the atmosphere, *J. roy. meteor. Soc.* **82,** 354, 409–418, Oct. 1956.

Authors use an original numerical method to calculate a stream function for the 500-millibar flow, using the "balance equation" which relates the wind to the geopotential in nondivergent flow. Three examples are discussed in which 24-hr time integrations of the atmospheric equations of motion are expressed in terms of the 500-millibar geopotential and 1000–500 millibar thickness. The effect of replacing the 500-millibar geopotential by a stream function is studied. In two cases there was little difference in the calculated charts, but in one case the use of the stream function improved the results.

J. S. Sawyer, England

1982. Hayashi, E., Sekiguchi, Y., and Yada, A., On solar radiation error and its correction of Japanese radiosonde, *Geophys. Mag., Tokyo* **27,** 3, 361–374, Sept. 1956.

Paper describes laboratory experiments to determine error in air temperature measurement caused by solar radiation falling on shielded bi-metallic radiosonde elements. Comparisons are given of corrections for sondes of American, Finnish, and Japanese designs. Reviewer believes that the omission of corrections for long-wave radiation might lead to serious errors at high altitudes.

A. Whillier, South Africa

1983. Rosinski, J., and Lieberman, A., Automatic isokinetic sampling, *Appl. sci. Res. (A)* **6,** 2/3, 92–96, 1956.

An automatic device was constructed for sampling air isokinetically. The automatic feature consists of a motor-operated bypass valve controlled by a Wheatstone bridge. Transducers, sensitive to changes in air velocity, are the sensing elements in the bridge. Experimental results are given in which the controlled sampling velocity was shown to follow changes in wind velocity very accurately.

From authors' summary

1984. Glansdorff, P., Rusconi-Muller, C., and Caignet, P., Temperature gradient in a column of saturated air (in French), *Acad. roy. Belgique Bull. Cl. Sci.* **42,** 6, 721–725, 1956.

Authors studied the temperature and specific volume gradients in a coal mine shaft, 800 m deep, in which saturated air was flowing quietly upwards. It appeared that both gradients fitted the pseudoadiabatic expansion of such a saturated gas. The measurements are in excellent agreement with the calculated values of temperature and specific volume.

K. W. Taconis, Netherlands

Lubrication; Bearings; Wear

(See also Rev. 1754)

1985. Fuller, D. D., and Sternlicht, B., Preliminary investigation of minimum oil-feed rates for fluid-film conditions in journal bearings, *Trans. ASME* **78,** 6, 1193–1200, Aug. 1956.

After discussing the applicability of Needs' results to the problem of determining the minimum volume of lubricant which must be fed to a bearing for it to operate hydrodynamically, authors describe experiments in which this quantity is measured. The amount of lubricant fed to the bearing was progressively reduced until friction became erratic. This was taken as an indication that the limit of purely hydrodynamic lubricant had been reached. Experimental conditions were as follows: shaft diameter 2¼ in., two bearings of breadth-diameter ratio of unity with diametral clearances of 0.0034 and 0.0045 in., respectively, and one of breadth-diameter ratio of 0.8 and 0.0045-in. clearance. Speeds were 1230, 1800, and 3500 rpm, respectively, and experiments were carried out at loads of 2, 40, 150, and 360 psi. Viscosity of lubricant was 47 centipoises at 100 F and 23 at 130 F, respectively.

Results are given in empirical formulas but, in their closure to the discussion, authors adopt Dubois and Ocvirk's load number [AMR 9, Rev. 347]. "Oil flow factor" varies logarithmically with "load number" over a wide range. At high values of the latter (high loading in relation to speed, viscosity, and dimensional factors) the curve flattens out to give an oil requirement equal to about 1% of that calculated by narrow bearing theory for normal operation.

The study and conclusions are important from the point of view of bearing design. Authors do not state explicitly that friction falls as lubricant supply is reduced toward the minimum but, if this is so, it may be desirable to deliberately restrict the amount of lubricant supplied to a bearing.

F. T. Barwell, Scotland

1986. Skinner, S. M., Gaynor, J., and Sohl, G. W., Electrical effects accompanying the stick-slip phenomenon of sliding of metals on plastics and lubricated surfaces, ASME Ann. Meet., New York, N. Y., Nov. 1956. Pap. 56–A–163, 8 pp. + 19 figs.

The electrical transients which accompany the stick-slip phenomenon in boundary lubrication have been investigated by an apparatus which permits simultaneous oscillographic measurement of any two of: the instantaneous load, the instantaneous frictional drag, the electrical transient potentials, during the stick-slip motion. The phenomenon has been investigated with unlubricated metal-metal contact using four metals in various combinations, lubricated metal-metal contact using various combinations of metals and five lubricants, and metal-plastic contact; in all cases, the contact was a sliding contact at low speed, since this accentuates the stick-slip phenomenon. Definite time correlation between the mechanical stick-slip and the electrical transients has been found. The characteristics of the electrical discharge appear to favor a charge-discharge mechanism rather than a thermoelectric potential or a dielectric breakdown mechanism, although further experiments are necessary to provide unambiguous proof of such a conclusion. Certain related frictional experiments were performed which, however, also favor such a mechanism.

From authors' summary

1987. Kettleborough, C. F., The tapered-land thrust bearing, *J. appl. Mech.* **23,** 4, 581–583, Dec. 1956.

Lord Rayleigh found that the maximum load capacity per unit width can be obtained with a thrust bearing in which the oil film possesses a stepped convergence. It is larger by 29% than the load capacity of a tilting-pad bearing. Lord Rayleigh obtained this result from a calculation in which side leakage was neglected. Archibald shows that the superiority of a stepped bearing becomes negligible if side leakage is taken into account. This is due to the fact that, in a stepped bearing, the oil can escape easier than in a tilting-pad bearing, because the film thickness in a stepped bearing still possesses its maximum value at the point of maximum pressure.

After this statement author compares the load capacity of a tapered-land bearing with that of a tilting-pad bearing. Starting from Reynolds' equation and paying regard to side leakage, he calculates load capacity and friction number, using a relaxation method. He finds that the maximum load which can be supported by a tapered-land bearing is larger by 14% than that which can be supported by a tilting-pad bearing. While the tilting-pad bearing, by reason of its adjustibility, can maintain optimum conditions, i.e., a constant optimum film-thickness ratio h_1/h_2, if the operation conditions are changed, it is not so in the case of a tapered-land bearing, in which not the film thickness ratio h_1/h_2 but $h_1 - h_2$ remains constant. The tapered-land bearing has the advantage only if the film-thickness ratio possesses a value between 1.69 and 3.16.

U. Rost, Germany

1988. Kettleborough, C. F., The hydrodynamic pocket thrust-bearing, *Instn. mech. Engrs. Proc.* **170,** 9 pp., 1956.

An electrical analogy technique compares foremost hydrodynamic thrust bearing configurations to find that theoretically the stepped-thrust bearing (pocket reduced to zero) operates with maximum load capacity and minimum friction. However, pocket bearing has potential of being best if optimum shapes are determined by further studies.

F. Macks, USA

1989. Hanau, H., Ball bearings for high speeds, *Mach. Design* **28,** 23, 88–106, Nov. 1956.

1990. Anderson, W. J., Effect of three design parameters on the operating characteristics of 75-millimeter-bore cylindrical roller bearings at high speeds, *NACA TN* 3772, 37 pp., Oct. 1956.

Three experimental investigations were conducted with 75-mm-bore (size 215) cylindrical roller bearings to determine the effects of roller axial clearance ratio, cage diametral clearance ratio, and cage land (locating surface) width-diameter ratio on bearing operating temperatures, wear, cage slip, and high-speed operating characteristics. Thirty test bearings were operated over a range of DN (product of bearing bore in mm and shaft speed in rpm) values from 0.3×10^6 to 2.1×10^6, at radial loads of 7, 113, and 368 pounds, and at oil flows of 2.0, 2.75, and 5.5 pounds per minute.

From author's summary

1991. Anderson, W. J., Macks, E. F., and Nemeth, Z. N., Comparison of performance of experimental and conventional cage designs and materials for 75-millimeter-bore cylindrical roller bearings at high speeds, *NACA Rep.* 1177, 15 pp., 1954.

The results of two investigations, one to determine the relative merits of four experimental and two conventional design 75-mm-bore (size 215) cylindrical roller bearings and one to determine the relative merits of nodular iron and bronze as cage materials for this size and type of bearing, are reported herein. Nine test bearings were operated over a range of DN values (product of bearing bore in mm and shaft speed in rpm) from 0.3×10^6 to 2.3×10^6, radial loads from 7 to 1613 pounds, and oil flows from 2 to 8 lb/min with a single-jet circulatory oil feed.

Of the six bearings used to evaluate designs, four were experimental types with outer-race-riding cages and inner-race-guided rollers, and two were conventional types, one with outer-race-guided rollers and cage and one with inner-race guided rollers and cage. Each of these six test bearings was equipped with a different design cage made of nodular iron.

From authors' summary

1992. White, H. S., Small oil-free bearings, *J. Res. nat. Bur. Stands.* **57,** 4, 185–204, Oct. 1956.

An investigation was made of materials that may be suitable for use as oil-free bearings in aircraft clocks and similar instruments between −55 and +70 C, to replace lubricated jewels that do not give satisfactory operation at subzero temperatures because of congealing of the oil. Another advantage of an oil-free instrument is the freedom from cleaning and oiling periodically during shelf storage. Materials included in the investigation were plastics, plastics with fillers, impregnated metals, and impregnated carbon. Friction tests were made with an inclined-plane type of static-friction apparatus, and with shafts rotating in loaded journal bearings, at temperatures from −55 to +70 C. With bearings of typical materials stored on steel shafts, the effect of shelf storage on static friction was investigated. Wear tests were made with loaded bearings on ¼-in.-diam rotating shafts made of different types of steel. With oscillating ⅛-in.-diam shafts and 1000-gram loads, wear data were obtained on bearings of the more promising materials. Using an endstone wear testing machine, wear data were obtained for end-thrust bearings made of typical bearing materials. The performance of oil-free bearings in 18 timepieces was investigated.

From author's summary

1993. Shaw, J. D., and Knopp, W. V., A new oil-less bearing material, *Prod. Engng.* **28,** 1, 203–205, Jan. 1957.

Characteristics and properties, advantages and limitations of full density graphite-metal powder combinations, self-lubricating even at extreme temperatures and pressures, are presented.

From authors' summary

Marine Engineering Problems

(See also Rev. 1712)

Book—1994. Manning, G. C., The theory and technique of

ship design, Cambridge, Mass., The Technology Press of the Massachusetts Institute of Technology; New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1956, x + 278 pp. $10.

A comprehensive book which is addressed, according to the preface, both to the shipping executive and to the designer. The book might be considered a study of the basic principles for the design of both merchant and war ships. Correspondingly, all important aspects of the problem are covered, viz., preliminary and final design, stability, lines, strength and weight. However, reading is sometimes made difficult because the wide scope of the author's subject is condensed on about 280 pages.

H. W. Lerbs, Germany

1995. Voitkunsky, Ya. I., On the selection of optimum ratios of the transverse dimensions of a vessel with reference to the clear cross section of the channel (in Russian), *Trudi Leningr. korablestroit. in-ta* no. 12, 33–40, 1954; Rev. no. 874, *Ref. Zh. Mekh.* 1956.

A description of tests with a model of an inland craft in a channel of rectangular cross section. The tests show that, retaining constant depth of the channel and speed of the vessel, the resistance of the hull increases at subcritical and decreases at transcritical speeds, as the width of the channel is increased.

Courtesy of Referativnyi Zhurnal M. D. Khaskind, USSR
Translation, courtesy Ministry of Supply, England

1996. Bazilevsky, A. N., An instrument for controlling the transverse stability of ships (in Russian), *Nauch. tr. Odessk. in-ta inzh. mor. flota, Jubilee edition, Moscow*, 122–131, 1955; Rev. no. 870, *Ref. Zh. Mekh.* 1956.

A description of an electrical computer for controlling the stability of ships. The instrument enables the following calculations to be made: (1) Determination of the transverse metacentric height from the loading condition of the ship; (2) determination of the stability characteristics; (3) calculation of the change in loading required in the case of deficient stability.

Courtesy of Referativnyi Zhurnal N. N. Moiseev, USSR
Translation, courtesy Ministry of Supply, England

1997. Pavlenko, V. G., On the calculation of the pitching motions of a ship in waves (in Russian), *Nauch. tr. Odessk. in-ta inzh. mor. flota, Jubilee edition, Moscow*, 142–156, 1955; Rev. no. 868, *Ref. Zh. Mekh.* 1956.

An investigation of the known elementary equations of the pitching of a ship in waves [cf. G. E. Pavlenko: "Theory and calculations of the pitching motion of a ship", L. K. I., 1939].

A graphical method of calculating the flooding of a ship during pitching is given. N. N. Moiseev, USSR
Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

1998. Pavlenko, V. G., An investigation of the principal oscillations in the pitching of a ship (in Russian), *Nauch. tr. Odessk. in-ta inzh. mor. flota. Jubilee edition, Moscow*, 132–141, 1955; Rev. no. 867, *Ref. Zh. Mekh.* 1956.

Article deals with the elementary investigation of the unconstrained oscillations of a ship in pitching. Within the scope of the conventional linear theory, which assumes the hydrodynamic problem to be solved, the known equations (e.g., those of M. D. Khaskind) for the combined longitudinal and vertical oscillations are assembled in simplified form, and expressions derived for the natural frequencies involved. Some curves are reproduced, showing the relations between these frequencies and the characteristic parameters of the ship. N. N. Moiseev, USSR
Courtesy of Referativnyi Zhurnal
Translation, courtesy Ministry of Supply, England

Books Received for Review

CALLAHAM, L. I., Russian-English technical and chemical dictionary, New York, John Wiley & Sons, Inc., 1947, xvii + 794 pp. $16.50.

CARAFOLI, E., High-speed aerodynamics. Compressible flow, Bucharest, Editura Tehnica, 1956, 710 pp.

COLE, E. B., Theory of vibrations for engineers, 3rd revised ed., New York, The Macmillan Co., 1957, xiv + 362 pp. $6.00.

DOOLITTLE, J. S., Mechanical engineering laboratory (Instrumentation and its application), New York, McGraw-Hill Book Company, Inc., 1957, ix + 396 pp. $6.50.

ECK, B., Ventilatoren. Entwurf und Betrieb der Schleuder-und Schraubengebläse, Berlin, Springer-Verlag, 1957, xi + 493 pp. DM 45.

EIRICH, F. R., edited by, Rheology, Volume I, Theory and applications, New York, Academic Press Inc., 1956, xiii + 761 pp. $20.00.

The first one hundred and fifty years; A history of John Wiley and Sons, Inc., New York, John Wiley & Sons, Inc., 1957, xxv + 242 pp. $7.50.

GIRKMANN, K., Flächentragwerke. Einführung in die Elastostatik der Scheiben, Platten, Schalen und Faltwerke, 4th ed., Wein, Springer-Verlag, 1956, xviii + 596 pp. $15.70.

GRABBE, E. M., edited by, Automation in business and industry, New York, John Wiley & Sons, Inc., 1957, xix + 611 pp. $10.00.

GULDAN, R., Elementare Baustatik für Studium und Praxis, Wein, Springer-Verlag, 1956, xvi + 295 pp. $9.30.

Handbook on aerial application in agriculture, College Station, Tex., A. & M. College of Texas, 1956, 146 pp. $2.50. (paperbound)

KAUFMANN, W., Statik der Tragwerke, 4th. enlarged and improved ed., Berlin, Springer-Verlag, 1957, viii + 327 pp.

LEONHARDT, F., and BAUR, W., Vorspannung mit fonzentrierten Spanngliedern, Berlin, Verlag Von Wilhelm Ernst & Sohn, 1956, 88 pp. DM 16.

LUZADDER, W. J., Graphics for engineers, New York, Prentice-Hall, Inc., 1957, x + 597 pp. $8.65.

MABIE, H. H., and OCVIRK, F. W., Mechanisms and dynamics of machinery, New York, John Wiley & Sons, Inc., 1957, xii + 442 pp. $8.50.

NEAL, B. G., The plastic methods of structural analysis, New York, John Wiley & Sons, Inc., 1957, xi + 353 pp. $7.50.

OWER, E., and NAYLER, J., High speed flight, New York, Philosophical Library, Inc., 1957, 227 pp. $10.00.

PAI, S-I., Viscous flow theory, Vol. II. Turbulent flow, New York, D. Van Nostrand Co., Inc., 1957, xi + 277 pp. $6.75.

PEACH, M. O., A modern course in engineering statics, South Bend, Indiana, University of Notre Dame, 1956, viii + 86 pp.

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